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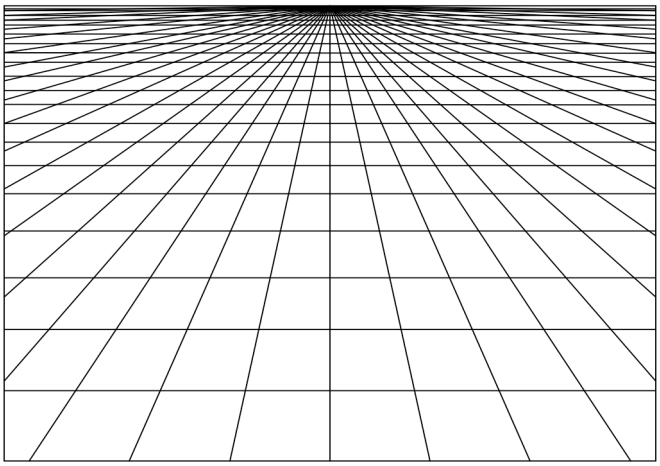

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The Technology Transfer Process - A Study of NTNU TTO

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SYNOPSIS

Over the years there has been an increased belief in university's role as contributor to innovation. This has led to new policies that further have led to establishment of technology transfer offices (TTO) at most universities. This thesis analyses the characteristics of the technology transfer process of a newly established Norwegian TTO.

The introduction of a TTO as a new actor in an already established relationship between university and industry denotes some tensions. These tensions are illuminated in this thesis through the study of the NTNU TTO and the selection phases of the technology transfer process against the backdrop of previous studies of TTOs and the concepts of national innovation systems and the "triple helix". Five phases of selection are identified: (1) research phase; (2) assessment phase; (3) development phase; (4) proof of technology phase and finally (5) transfer phase. This model captures the different actors and their relations.

The analyses show that the NIS and the triple helix are complementary, and not contrasting, concepts for analysing the technology transfer process and the relation between the participating actors. Further it argues that several tensions are evident in the technology transfer process. This is apparent in TTO's relations towards its owner, the researchers, the industry and the system as a whole.

Key words: TTO; technology transfer; selection phases; tensions

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1 Introduction

The perception of the university's role in society and economy has changed the past three decades. The university is now expected to contribute more directly to innovation and economic development, as knowledge has become the new commodity in the new economy (Florida and Cohen 1999). This is especially evident in the increased establishments of technology transfer offices (TTO) at the universities. The purpose of a TTO is to enhance and facilitate technology diffusion through the licensing of inventions or intellectual property resulting from university research to industry (Siegel *et al.* 2003). An introduction of a new organisation, like a TTO, into the university – industry relationship denotes some tensions, as it has to find its own place in an already established system. These tensions and the characteristics of the technology transfer process are the central focus of this thesis.

The university's role is thus no longer limited to teaching and researching. The development of new high-opportunity technology platforms such as computer science, molecular biology and the more general growing scientific and technical contents of all types of industry production, have led to policies aimed at raising the economic returns of publicly funded research by stimulating university technology transfer (Bercovitz and Feldmann 2006). Accordingly, the success of academic led innovations in technology based regions like Silicon Valley and the Route 128 have inspired, among others, policy makers to conclude that the university plays a fundamental role in developing technological innovations and technologies that powers the economic growth of the region. For this reason, many countries have adopted an increasingly more specific and explicit strategy of using the university as an engine for economic growth and innovation.

The Bayh-Dole Act, enacted in 1980 in the US, is an articulation of the belief in the universities' enhanced role in innovation. It promotes the utilization of inventions arising

from federally supported research, and supports the commercialisation and the public availability of inventions (Renault 2006). Trough the Act the ownership of inventions originating from university research was transferred from the State to the research institutions.

The Bayh-Dole Act was emulated in Norway by the amendment to the Act on Universities and Colleges and to the Act relating to the right to inventions made by employees in 2003 with the aim of increasing the commercial exploitation of academic research results. However, there is one major distinction. The ownership of the inventions was in Norway transferred from the researchers to the research institution. This implies that the researchers – the inventors, were deprived of a privilege. In order to handle and administer the new regulations and the technology transfer process, all universities in Norway have now established TTOs.

This thesis will investigate the elements of the technology transfer process and the tensions surrounding it through the case study of the Norwegian University of Science and Technology (NTNU) Technology Transfer Office (TTO). This is examined through the research question:

What characterises the technology transfer process of a newly established TTO?

The question is analysed against the backdrop of literature on TTOs and the concepts of national innovation systems (NIS) and "triple helix". First the elements of the technology transfer process and the features of a TTO organisation are reviewed through the burgeoning literature on TTOs. Second the concept of innovation in evolutionary theory will be outlined, within which the concepts of NIS and triple helix confines to. The NIS and the triple helix reflect different opinions on the role of the university in innovation, and thus different perceptions of the effect and the role of the TTO in technology transfer process. Proponents

of the NIS concept argue that academic technology transfer mechanisms like the TTO may create unnecessary transaction costs by encapsulating knowledge in patents which would otherwise flow freely to industry (Mowery and Sampat 2005). On the other hand, the proponents of the triple helix perspective argue that universities have a central and active role in economic growth and innovation. They claim that the TTO facilitates the knowledge transfer with its mechanism for identifying and enhancing the applicability of research (Etzkowitz and Leydesdorff 2000).

This thesis argues that even though these two concepts are contrasting they are complementary for analysing the technology transfer process. It further argues that there are several tensions surrounding the TTO that must be considered in an assessment of the technology transfer process. These tensions are a result of the conflicting position of the TTO, and can be observed in its relations towards the researchers, its owner, in its strategy and in the concepts of NIS and triple helix.

First, this thesis will present the conceptual framework described above (chapter 2), then the methodology used in this thesis will be outline (chapter 3). The next chapter (4) presents the context and the background for the establishments of TTOs. Then the case of the NTNU TTO is presented and analysed through the conceptual framework (chapter 5 and 6). Finally, the findings are discussed and conclusions are drawn (chapter 7).

2 Conceptual framework

The conceptual framework is divided into two main parts. First the characteristics of the technology transfer process and the features of a TTO will be presented. Then the concept of innovation in an evolutionary perspective, NIS and triple helix will be outlined and explained.

2.1 The technology transfer office

The role and the "best practice" of the Technology Transfer Office (TTO) are widely debated. Even the term "technology transfer" is an object of discussion. There are those who claim that the term in it self indicates a linear process. Others claim that this is an interactive process, and that there is no linear direction on the technology transfer process. This thesis will argue with the latter.

A TTO is by definition a formalisation of university – industry technology transfer. Its purpose is to facilitate the diffusion of technology through the licensing to industry of inventions or intellectual property resulting from university research (Siegel *et al.* 2003). The work of the TTO involves many features and variables. Some of them will be reviewed in this chapter.

2.1.1 Core elements

A key input to the technology transfer process is the disclosure of inventions. A disclosure is the reporting of research results that could be of commercial potential. The disclosure is reported in through a form which serves as a formal document on the invention. This is the material that the TTO personnel get to work with, and these make up the pool of available technologies for licensing or other results that may have commercial value. Other inputs to

the technology transfer process can be identified as the labour employment by the TTO- their competence and organisation, and legal fees incurred to protect the university's intellectual property (Siegel *et al.* 2003a).

Bercovitz and Feldman (2005) define core elements in the university- industry relationships as transactions that occur through the mechanisms of sponsored research, licensing/patents, hiring of research students and new spin-off firms[1]. Consulting agreements with individual faculty are outside the university technology transfer purview - the company usually already owns the intellectual property rights (IPR).

Sponsored research is defined as a contract between the firms and the academic entity. A sponsored research project may provide resources for infrastructure, students, course releases and summer support for faculty members. Sponsored research is an important input to the technology transfer process, as this enables research for possible inventions and a continuation in the development of an invention. Governments are usually the main provider of sponsored research through their programmes and councils. Government funding is normally more directed towards basic research and is less restricted than industry funding, which is more focused on later stages in the development process of an invention. Sponsored research may take the form of grants or contracts. Contracts are an often-disputed issue in sponsored research concerning the ownership of any resulting IPR, details for licensing, division of royalties and future research projects. These issues are difficult to solve and enquires tailor-made contracts for each project.

University licenses are another contractual technology-transfer mechanism. These provide the right for companies and others to use university IPR in the codified form of either patents or trademarks. Licensing agreements differ in terms of their specification and scope. They vary highly in price, whether they are exclusive or non-exclusive, level of the royalty

[1] They also include serendipity as an informal mechanism that might be used to initiate a relationship, which subsequently develops through other mechanisms. I will not use this variable in this thesis

rates, publication delay allowances, and duration and future options rates (ibid.). According to Markman *et al.* (2005) there are three different licensing strategies that the university can employ: licensing in exchange for sponsored research, licensing for equity and licensing for cash.

A survey of TTOs found that only 12% of licensed technology is ready for commercialisation (Jensen and Thursby 2001). Thus a majority of the licensed technology requires significant development. These contracts are negotiated before the actual value of the contract is known and the research is complete. Hence, the negotiated contracts are based on estimates of the expected value of the knowledge. This imperfect estimate may entail a market failure – the contractual price may significantly differ from the actual social value. Increased licensing activity is the most visible and measurable output of technology transfer. It is perceived as an indication on the university's enhanced role in economic development (Bercovitz and Feldmann 2005).

Hiring of students and spin-off companies are more direct outputs as they involve movement of people. University spin-offs are seen as means to transform local economies, especially after the successes of Silicon-Valley and Route 128. A spin-off is a firm that is formed by the university, faculty or staff. It is formed around a university license or intellectual property. The firms can also be a student spin-off. Spin-offs are often located geographically near the university. The technology can be licensed out to a company in the process of starting up, but this does not necessary have to entail university personnel as an experienced entrepreneur can be hired (Bercovitz and Feldman 2005, Vohora *et al.* 2003).

It should be mentioned that the inputs and outputs described above are only the measurable indicators of technology transfer. There are certainly many other different interactions between university and industry that the metrics of the technology transfer do not capture. This could be informal interaction between the two that takes the form of

conferences, meetings, consulting and cooperative R&D projects. Publications and reports also play major roles in this interaction (Mowery and Sampat 2005).

2.1.2 The technology transfer process

In theory and in superficial description, the technology transfer process starts with a scientific discovery that is disclosed to a TTO. The TTO then evaluates the invention according to whether it can be patented or copyrighted in order to protect their intellectual property. The invention is also evaluated on its commercial potential. The invention often gets exposed to the market to prove the interest for the invention, and this is often sufficient to file for a patent. Then the product will be marketed and the TTO will work either with already established firms or try to create a spin-off (fig.1). Through this process, some inventions will be selected for further commercialisation, while others will be rejected according to the different selection criteria employed by the TTO and other agents of the commercialisation process. The typical stakeholders in this process are university scientists, the TTO, governmental organisations and firms/entrepreneurs.

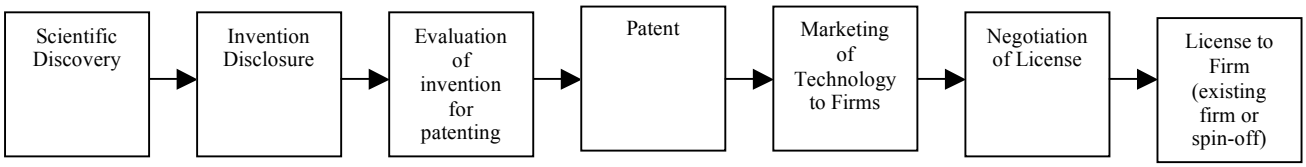

Figure 1 [2] How an invention is transferred from a university to industry

Source: after Siegel *et al.* (2003 b)

[2] This model bears resemblance with the so-called linear model. This alleges that the process of innovation has a linear direction. The purpose with the figure is to indicate the process, without describing its complexity, as this will be elaborated in the following chapters.

Through this process there will probably be a development of the invention disclosed. Markman *et al.* (2005) has identified the overlapping stages of development as:

- Early stage: the idea of a new technology. The exact mechanisms and the possible functions have not yet been identified.
- Proof of concept: the idea or technology has been developed to a point were it shows signs of having the proposed effect.
- Reduction to practice: an experiment on the idea has been replicated several times and the results are reliable.
- Prototyping, formulation, compound: the new technology can now be constructed as a reliable method of producing a given result. At this stage the new technology might be applied in new and different settings.

An invention can be disclosed to the TTO in all of the stages described above. This is dependent upon what kind of research it confines to.

Different types of research generate different types of new knowledge. Stokes classifies these into four distinct quadrants functioning along two dimensions: “Quest for fundamental understanding” and “Consideration of use” (Faley and Sharer 2005). The four quadrants are labelled (fig. 2.): 1. “Bohr”, this is pure basic research aimed at increasing general understanding. 2. “Pasteur”, which is research that increases fundamental understanding, but is initiated with a consideration of use. 3. “Research training”, which is research for the sake of training the researchers. This does not increase fundamental understanding and it cannot be commercially applied. 4. “Edison”, this is applied research that is ready for commercialisation.

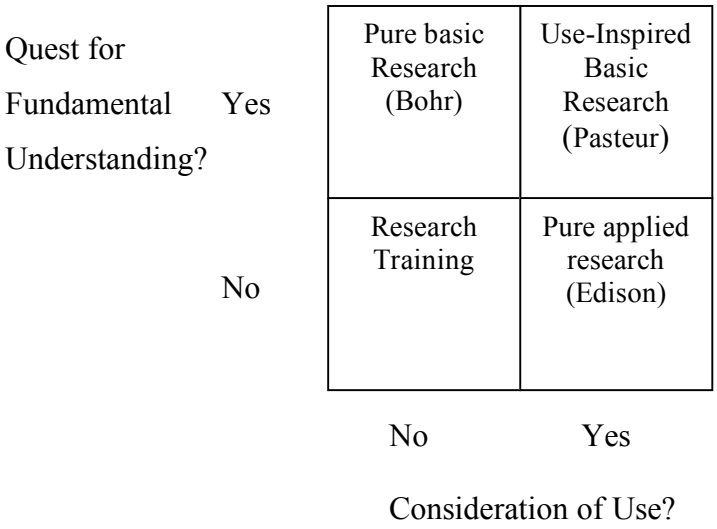

Figure 2 Stokes' quadrant framework to determine the different types of research.

Source: Faley and Sharer (2005)

From this model one can interpret that the Pasteur quadrant will be the type of research that has the highest potential for successful technology transfer through a TTO. The Pasteur quadrant also has the potential to simultaneously expand fundamental understandings and be incorporated into commercial products (ibid). Hence, this research can maximise the public benefit of research. Bohr's quadrant, on the other hand, consists of fundamental discoveries that build and renew the knowledge reservoir through expansion of the body of scientific knowledge. These discoveries normally have no immediate commercial application. Research results from Bohr's quadrant may also be disclosed to the TTO. These inventions are thus in an early stage of development.

Jensen *et al.* (2003) claims that roughly only 50 % of the inventions from a university are disclosed to a TTO. The disclosure of inventions is a critical element in the technology transfer process as they create the possibility for variation. A faculty may not disclose for a variety of reasons, one of them being that disclosure and development of the invention is a

time consuming process[3]. The quality of the disclosed inventions is also reported to be of questionable value. They are related to the quality of the faculty and to the perceived quality of the TTO (Owen-Smith and Powell 2001). The Edison quadrant research is usually not reported to the TTO, as there is no need of their expertise. Pasteur research may also be developed without the involvement of the TTO. Hence, the inventions disclosed to the TTO are in general in the early stage of development and confines to the Bohr quadrant which has an uncertain character (Colyvas *et al.* 2002). But, this may vary among TTOs. The more "wealthier" and successful TTOs discourage early stage inventions and encourage disclosure at the proof of concept stage (Jensen *et al.* 2003).

2.1.3 Organisational types and features

TTOs can be classified into three different categories, depending on their attachment to the university (ITTE 2004, Markman *et al.* 2005):

- Department- type
- Wholly owned
- Independent

The department type is characterised by localisation of the TTO within the university structure, often as a part of the university's administration or legal office. This organisational type gives the TTO a high proximity to researchers and ensures close links with research at the university. The personnel are normally untenured university staff with the primary role of pursuing conventional licensing opportunities for royalty income. Their strong inward orientation might have an effect on the marketing and professionalism of their transfers and management activities. Incentives to commercialisation in this structure may be rather weak as the personnel works on fixed salaries, and the organisation type is most likely to act as a

[3] Jensen et al. (2003) reports that faculty involvement in the commercialisation process is necessary in 71% of the cases.

liaison for contractual research. Thus, the outlook for royalty incomes is rather low (ITTE 2004, Markman *et al.* 2005).

The wholly owned TTO is characterised by being owned by the university, but functions as an independent non-profit unit. It is usually localised outside the university's administrative structure. This structure provides stronger legal protection for the university against lawsuits stemming from the university's licensed technology. It can also function as an intermediary between researchers and industry to avoid or solve conflicts of interest during the commercialisation process. The wholly owned TTOs enjoy having their own budget and thus greater autonomy. It will probably have a Board of Directors that is independent of the university, and the chairman of the board is usually the president of the university. In regards to personnel and incentives, the TTO usually enjoys greater flexibility for pay and thus has the possibility to employ personnel with different competencies. These TTOs provide most frequent liaisons for contract research and licensing for cash as their main service. The higher degree of managerial and financial independence from the university, the easier it is for the TTO to develop relationships with potential licensees and venture capitalists. The disadvantage with this organisation form is that there are higher transaction costs and more complex coordination with researchers (ITTE 2004, Markman *et al.* 2005).

Independent TTOs usually serve more than one research organisation, and are normally created as a separate private venture extension. They can be a part of the university structure. They have an independent CEO and a Board with personnel who have substantial experience in IPR law, managing companies and venture capitalism. The independent TTOs are focused upon economic development and creating spin-off companies. Advantages with this organisational type are that it has limited liability and enjoys flexibility in pay and

incentives towards its employees. It has the same disadvantages as the wholly owned (ITTE 2004, Markman *et al.* 2005).

The above can be summarized in a table:

TTO organisation type	Description	Key Features	Advantages	Disadvantage
Department type	Localised within the university structure, part of the university's administration.	TTO staff is university employees. Licensing for cash most employed.	Close contact with researchers	Strong inward orientation, can affect marketing and industry contact.
Wholly owned	Owned by the university, but a separate entity. Localised outside of the university administration.	Separate budget from the university. Board of Directors independent of the university. The President of the University is the chairman of the board. Liaison for revenue and licensing for cash most employed strategy.	Limits liability. General autonomy from the university; greater flexibility in pay and incentives, separate budget.	High transaction costs. Complex coordination with researchers.
Independent	Serving more than one research organisation. Either a part of the university structure or a research foundation.	Has an independent CEO and Board. Employees have start-up / VC experience. Creating spin-offs most employed strategy	Limited liability. Flexibility in pay and incentives.	High transaction costs. Complex coordination with researchers

Table 1 Organisation types and features

With reference to the organisation types, it seems obvious that the commitment from the university's administration and faculties towards the TTO is an important factor to enhance technology transfer. The university's articulation of technology transfer as its priority is required for successful technology transfer (Siegel *et al.* 2003b). Its attitudes have a strong effect on its employees as the university establish goals and priorities and espouse values pertaining to technology transfer.

The TTOs also differ with reference to internal organisation. Variables are size, age, legal expertise and whether they are specialised or not. TTOs employ on average 10 persons (ITTE 2004). It appears that the size of the TTO might have an impact upon the number of agreements, but does not necessarily give additional revenue (Siegel *et al*. 2003a). Size is thus of no significant relevance (Chukumba *et al.* 2005). The older the TTO is, the closer to the frontier it operates. This implies that there is a learning effect in the university management of intellectual property (Siegel *et al.* 2003a). Over time newer TTOs learn how to raise the quality of their patent portfolios (Mowery *et al.* 2001), and Chukumba *et al.* (2005) found that older and more experienced TTOs are more likely to license inventions to both spin-offs and established firms and they are also more likely to receive more disclosures.

Many universities are quite sensitive to the fact that they have previously been "giving away" university-based, taxpayer-funded technologies that yield substantial windfall profits (Siegel *et al.* 2003a). This has resulted in many TTOs adopting a hard line in licensing negotiations by using more legal expertise. However, spending more on (external) lawyers reduces the number of licensing agreements, but increases licensing revenues. This is probably due to that these negotiated inventions are more lucrative and thus needs more considered protection. The use of external lawyers is also a signal to the industry that the university will be aggressive in exercising its intellectual property rights (Siegel *et al.* 2003a). It seems now to be a tendency that firms avoid dealing with aggressive TTOs (ibid.).

It appears that specialised TTOs are more effective than unspecialised TTOs in terms of patents, revenue from licensing and spin-off formation. These are connected to departments like medicine, veterinary medicine, microbiology and biology, computer science, electrical engineering, chemistry and agriculture. TTOs specialising in science perform better than those specialised in other disciplines on supporting contract research (ITTE 2004). Many researchers on TTO assume that the presence of a medical school has an

effect upon licensing to established firms or spin-offs. This seems not to be of great significance, but findings suggest that these universities are more commercially oriented and it is easier to license their inventions to established firms. In addition they also have more inventions disclosed at an early stage (Chukumba *et al.* 2005, Jensen *et al.* 2003).

The effectiveness of the TTO is related to the competencies of the personnel. Many TTOs have recruited personnel with extensive discipline knowledge and with PhDs. Siegel *et al.* (2003b) found that they also look for expertise in patent law and licensing or technical expertise. They usually do not actively recruit personnel with marketing skills. According to Siegel *et al.*'s findings the TTOs should hire licensing officers and TTO managers with more substantial business experience, that can engage in boundary spanning roles and act as facilitators and negotiators of university-industry technology transfer. They also found that TTOs that was managed by directors with substantial business and negotiation experience, had much firmer grasp on how to assess the market potential of a particular technology and create more linkages with firms.

There are also discussions on whether incentives to technology transfer officers will enhance their effectiveness. Usually academics receive royalties from their commercialised inventions whilst the TTO personnel have a regular and fixed salary. Siegel *et al.* (2003b) indicates that a change in the incentive system will improve the TTOs' effectiveness. This is also a major point in regards to competencies that is demanded of an officer. Optimally they should have both discipline and marketing knowledge in order to communicate with both university and industry. Incentives to scientists and their departments were on the other hand negatively related to entrepreneurial activity (Markman *et al.* 2004). Hence, it seems like the reward system, and not incentives, is the most crucial instrument towards scientists and departments to enhance their productivity.

Today, faculty promotion and academic credibility are rewarded through the publication of papers and through peers. This implies other difficulties for the commercialisation of research results. One of the guiding ideas of the university has been the notion of open science and the university culture has been characterised by Humboldt's ideas[4]. This still appears to be prevailing in large parts of the university culture. Nelson (2001) argues for the open role of science and against the secrecy that surround patents. Knowledge should be disseminated in the most effective manner, and there should be no obstacles in this dissemination. He argues that a patent is a possible obstacle to this. Other proponents agree with Nelson and claim that the increasing patent activity over the past two decades is not due to the introduction of the Bayh-Dole Act. It is rather a result of new research areas like biotechnology and computer science (Mowery *et al.* 2001).

Attitudes towards the role of open and public science and the role of the reward system are well known to the TTO personnel. The implementation of an entrepreneurial university (Etzkowitz 1983), with its new institutions, often meets social inertia from scientists who identify themselves with the ideas mentioned above. Many TTOs experience that it is difficult to encourage and to get researchers to disclose their research results. However, on the contrary to what many would expect, it seems like scientists that are involved in university-industry technology transfer may be able to conduct better research and teaching (Siegel *et al.* 2003b).

The "third mission" has been implemented through different policies in different countries. The US has with the Bayh-Dole Act transferred the IPR to the universities, as has Norway, and the scientists are by law instructed to rapport inventions that might be of commercial interest. On the other hand, in most European countries scientists still enjoys, to a

[4] These are characterised by the unity of teaching and research, social disembeddedness and autonomy, and a non-utilitarian approach to higher education as opposed to purely vocational training. These factors are still part of the commonly shared understanding of what it means to be a university (Krüken 2003).

certain extent, the rights to their own inventions, but the universities are ordered executing the "third mission". There has not been identified any "best practice" in this area. These differences also express themselves in the TTO's approach to technology transfer. For example, there appears to be a difference between UK[5] and US. There is a greater focus on patenting in the US. The TTO's function is more as a patenting office than as a TTO. This has led to a debate on the role of the employees in TTOs, some claiming that they have a "police" role towards the researchers on campus. In UK, however, the TTO has a broader role in the technology transfer process and the focus is more on spin-off firm. The European TTOs tend to be more selective in applying for patents (Maartmann- Moe 2006, Rasmussen *et al.* 2005, ITTE 2004).

This chapter has described the many aspects of the TTO and the technology transfer process. There are many variables and factors that have to be present in order to create efficient technology transfer. The technology transfer process is dependent upon (among others) the licensing strategy, the organisational type and features and the researchers' attitudes towards TTO. The next chapter will outline the theoretical concepts that will be used in the analysis of the NTNU TTO and the technology transfer process.

2.2 Theoretical concepts

The technology transfer process from university research to commercialisation is characterised by multiple dynamics and interactions of different actors. This thesis will use the concepts of national innovation systems (NIS) and "triple helix" to illuminate the technology transfer process and the different selection criteria that are employed. There are many elements of the innovation process that is important to have as a background for understanding the dynamics of the two concepts. Hence, before introducing the two concepts, some general characteristics of innovation and the evolutionary perspective will be given.

[5] It appears like most of the research on European TTOs have been done in the UK

2.3 The concept of innovation

Triple helix and NIS are both within the evolutionary tradition. Evolutionary theory is a broad perspective for analysing economic change stemming from either shifts in production demand or factor supply conditions, or from innovation on the part of the firms (Nelson and Winter 1982). "The core concern of evolutionary theory is with the dynamic process by which the firm behaviour patterns and market outcomes are jointly determined over time" (ibid p. 18). The theory builds on the work of Schumpeter, and has grown with many perspectives. Evolutionary theory contrasts itself especially against new growth theory (NGT). The two approaches agree upon the importance of innovation for long run economic growth, but perceive the process of innovation differently. While NGT believes that there are perfectly rational agents endowed with perfect information, evolutionary theory argue that there is a population of heterogeneous bounded rational agents who try to find their way through trial and error. NGT perceives knowledge as a public good which would be freely available to everybody if it were not for legal institutions, while evolutionary theory assumes that economic knowledge is a distributed phenomenon that to a large extent resides in firms through their shared routines (Fagerberg 2003).

The term evolutionary derives from the biological concept with the same name. Evolutionary in a biological setting is the concepts of variety (mutation), selection and inheritance. These are also some of the key features of evolutionary theory. Variation and selection are considered as the dynamics of evolutionary theory (Fagerberg 2003). Firms evolve over time through the joint action of search and selection with the condition of the industry in each period, bearing the seeds of its condition in the following period (Nelson and Winter 1982). In this sense university research can be interpreted to contain new elements that can be used by firms in this search. The role of the TTO can then be interpreted to be a creator of possible variation for industry. Further, evolutionary theory argues that economic

growth is driven by variety, and the selection process improves the average performance. The whole process of technical innovation can be described as an ongoing search activity.

The biological concept inheritance is in evolutionary theory interpreted as the concept of path-dependency. In order to gain sufficiently from an innovation it is claimed that it is important to hold a first mover advantage. A problem with this is that such a focus may lead to problems that path-dependency may create (Fagerberg 2005). Path-dependency is defined as the outcomes of processes that consist of interactive systems for innovation and economic competitiveness, including industrial specialisation and specific knowledge bases, which have been developed over a long period (Wicken 2005). This implies that if a firm selects a specific innovation path very early it may enjoy first mover advantage, but also risks being locked in to this specific path through various self reinforcing effects. Path-dependency is thus an important selection mechanism. Research from the university contains new elements that often do not coincide with a country's paths. This raises some questions and problems for the TTO in choosing a possible commercialisation strategy. Companies could be locked into a certain path and may not be mature or ready for a new invention. This might be why many licenses from TTOs are sold on the global instead of the local market. This might also explain why there hitherto has been a focus on spin-off establishments in Norwegian TTOs.

Innovation is in evolutionary economics regarded as a result of continuous feedback and loops mechanism between the market forces and the forces of progress in science and technology. Kline and Rosenberg (1986) describe this process with their chain-linked model of innovation. Invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out in practice. These processes can be closely linked or there can be a substantial time lag between them. Kline and Rosenberg further argue that the innovation process is inherently uncertain. Innovation implies creating novelty, and a novelty contains elements that we do not comprehend at the beginning and about which we

are uncertain. Thus innovation is a continuous learning process. There are also different levels of uncertainty depending on the dimension of the innovation – whether they are so-called incremental or radical. In particular for radical innovation one may simply not know what are the most relevant sources or best options to pursue (Fagerberg 2005). Through the innovation process and the development of the product or the process, uncertainty will be reduced. Consideration of uncertainty helps us understand why different criteria apply and different problems occur in innovation at different times in the production cycle of a product (ibid.).

Openness to new ideas and solutions is of great importance for innovation. The growing complexity of the knowledge bases, and the fact that every new innovation consist of a new combination of existing ideas, capabilities, skills, resources etc, means that a firm needs to interact with external sources. This implies that a firm does not innovate in isolation, but depends on extensive interaction with its environment. Thus, cultivation of absorptive capacity is a must for innovative firms (Cohen and Levinthal 1990).

Commercialisations from the university are among other variables dependent upon the absorptive capacity of firms. The role of the TTO is to facilitate the dissemination of knowledge from the university to the industry. In this process they must work closly with industry in order to encourage an extensive interaction between the two spheres.

"Innovation" can further be divided into different categories. First, there are two major types of innovation, product- and process (which also includes organisational) innovations. Second, these innovation categories can be classified into incremental and radical innovations and technological revolutions. Incremental innovations are characterised by being continuous improvements of a product or a process. Radical innovation is the introduction of a totally new type of machinery or process, whilst technological revolutions consist of a cluster of innovations that together have far-reaching impact. The TTO can

experience to have disclosed inventions that can have the potential in all categories. Radical innovation can for example descend from Bohr, Pasteur and Edison research. They can either introduce something new or they can replace something old. In case of the latter, this appears to be difficult to commercialise. These innovations will always experience social inertia and resistance from the proponents of the existing paradigm (Fagerberg 2005). Thus in these cases it will be difficult for the TTO and the university research to gain credibility. However, if the innovation introduces something new, it will not be perceived as threatening and the commercialisation process will be more straightforward. Mostly however, it appears like the inventions from the university and the TTO are of an incremental character.

2.4 National innovation system

The national innovation system (NIS) concept builds upon, as mentioned previously, evolutionary theory. Below, the concept's origins and elements are outline, and the university's role in the NIS is explained.

2.4.1 The origins of the concept of national innovation system and its elements

Freeman launched the concept of national innovation system (NIS) in 1987. Later, several other researchers among others Lundvall, Nelson and Edquist have further developed the concept. The overall aim of the NIS concept is to study the process of innovation in its systemic context. The main function of a NIS is to pursue innovation processes, i.e. to develop, diffuse and use innovations (Edquist 2005).

The definition of the NIS concept is a bit blurred – it consists of different interpretation and concepts. Edquist (2005) provides a general definition of a NIS. He

includes all important economic, social, political, organisational, institutional and other factors that influence the development, diffusion and use of innovations. The main components of the system are organisations and institutions. "Organisations are formal structures that are consciously created and have an explicit purpose" (Edquist 2005, p.188). These are firms (suppliers, customers, competitors), universities, venture capital organisations and public agencies responsible for innovation policy, competition policy or drug regulation. "Institutions are sets of common habits, norms, routines, established practises, rules or laws that regulate the relations and interactions between individuals, groups and organisation" (Edquist 2005, p.188). The organisations can be defined as the actors in the system whilst the institutions are the rules of the system.

Lundvall and Nelson have developed the NIS concept in two major books, but have employed different approaches to the study of NIS. Nelson (1993) emphasises empirical case studies and has a more narrow focus on R&D systems. He interprets innovation broadly to "… encompass the process by which firms master and get into practice product designs and manufacturing processes that are new to them, if not to the universe or even to the nation" (ibid. p.4). Hence, he defines the innovation process to be located in the industrial laboratories and firms.

Lundvall (1992) on the other hand, combines the idea of systems of innovation and interactive learning. This implies that innovation should be regarded as a gradual and cumulative process and that interactive learning and collective entrepreneurship are fundamental to the process of innovation. Interactive learning is different from the knowledge production at the R&D laboratories. The experience of workers, production engineers, sales representatives etc form the basis for correction and improvements. Hence learning by doing, learning by using and learning by interaction feedback into the process of innovation. If innovation reflects learning, and routines have a central role in the learning process, then

innovation must be rooted in the prevailing economic structure. Areas where technical advance will take place will primarily be those where a firm, or a national economy, is already engaged in routine activities. Lundvall further argues that the structure of production and the institutional set-up are the two most important dimensions that jointly define a NIS.

Hence, there are different interpretations of a NIS- it can analyse both macro and micro levels of the system. However, there seems to be an agreement between the developers of the concept that innovation is located within firms and the industrial laboratories.

2.4.2 The role of the university in the National Innovation System

The university is perceived in the NIS concept first and foremost as an indirect contributor to innovation. It provides industry with "human capital", like trained scientists and engineers. The university also operates as a source of research findings and techniques of relevance to technical advance in industry. Hence, the university has a modest role in innovation in the NIS concept.

Nelson (1993) argues that strong research at universities or in public laboratories aids a country's firm in innovation only in certain fields of research like pharmaceuticals, fine chemicals, agriculture and electrical engineering etc. Where universities do seem to be helping national firms, there tends to be either a direct interaction between particular firms and faculty members or research projects, or mechanisms that tie university to groups or firms. He further argues in an article (Nelson 2001) that there has not been an increase in innovation resulting from research results from the university after the implementation of the Bayh-Dole Act. This might imply that he perceives the role of a TTO as superfluous.

On a micro-level the relationship between the university and the industry can be more detailed. Firms can be identified as the users of and the university as a producer of scientific knowledge. According to Lundvall (1992) the relation between user and producer will condition the scope and direction of the process of innovation, and the institutional form and

set-up that characterises these relationships reflects the characteristics of the process of innovation. Firms (users) will invest time and resources in expanding their technical knowledge, and thus exploring becomes an important activity – creating inputs to the system of innovation. Scientific-activities often have a specific aim and direction, and the research is often oriented towards users on the outside. This brings forward another kind of raw material for the process of innovation. The relationship between firms and university must be characterised by a reciprocal flow of qualitative information. This interaction is not the same as a "market-pull" or "technology- push", which are in this sense artificial construct and close related to the linear model. The relationship is dynamic and is characterised by a continuous feedback and loop mechanisms between the two.

In this dynamic relationship it appears that university research will be commercialised only if industry finds it interesting. Thus, the main argument in the NIS perspective considering the role of the university appears to be that firms select and explore upon university research. With this argumentation it seems like path-dependency is unavoidable, but Lundvall states that exploring of university research will sometimes result in outcomes that adds to technological change because of its unpredictability. Exploring by firms may sometimes also result in breaks in cumulative paths and create the basis for new technological paradigms (ibid).

All together it appears like the NIS concept is insufficient to explain the role of the TTO in selection of invention for commercialization, since it focuses on that the main loci of innovation is within industrial laboratories and firms, and that the industry select upon the university. In the interaction between the industry and the university there are other elements and organisations that are decisive for the commercialisation process. The triple helix concept elaborates more on this relationship, as it argues that the university has an enhanced role in innovation in increasingly knowledge-based societies (Etzkowitz and Leydesdorff 2000)

2.5 Triple helix

These sections will first describe the elements that compose the "triple helix" and its functions. Then the role of the university in the triple helix concept will be explained.

2.5.1 The elements of the triple helix

The "triple helix" concept is concerned with the interactions between government, industry and university (Etzkowitz and Leydesdorff 2000). These are separated because of their institutional differentiation. There are several variations of these interactions, but there is a growing tendency towards a triple helix structure that is generating a knowledge infrastructure in terms of overlapping institutional spheres. Each of these spheres is taking the role of the other and hybrid organisations are emerging at the interfaces (fig. 3).

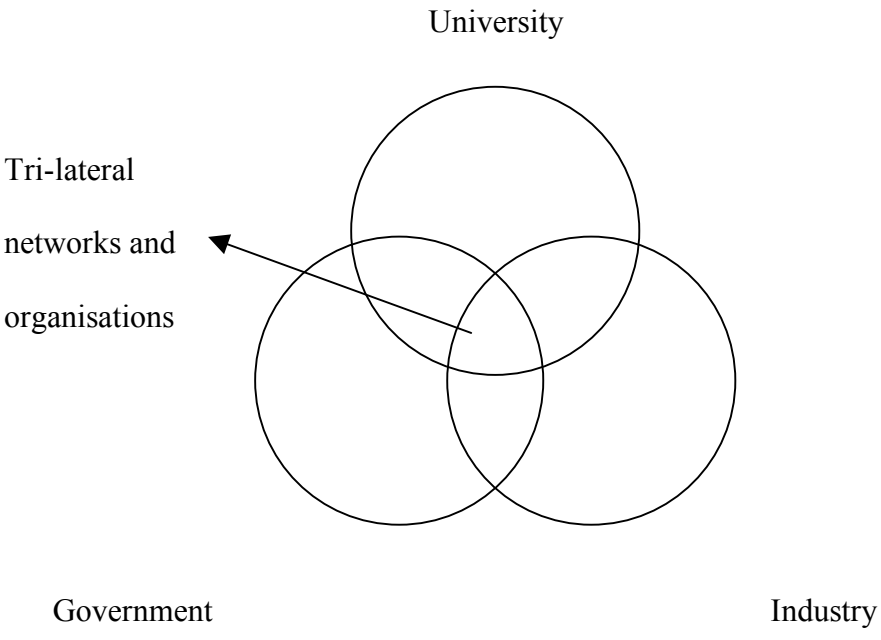

Figure 3 The triple helix model of university- industry- government relation

Source: Etzkowitz and Leydesdorff (2000)

The increase of interactions among the spheres has had the effect of generating new structures within each of them, and to the creation of integrating mechanisms among the

spheres, such as a TTO. Depending on the organisational type the TTO can be identified in the overlapping spheres. A department-type will typically be in the university sphere on the edge to the interfaces of the industry and the government sphere. The wholly owned and the independent type will probably be located in the middle of the figure, since these can be classified as tri-lateral organisations. They act as intermediaries between the university, government and industry. This will be further elaborated in chapter 6.

In contrast to the double helix a triple helix is not expected to be stable. A triple helix in which each helix may relate to the other two, can be expected to develop an emerging overlay of communication. The networks of relations generate a reflexive sub dynamics of intentions, strategies and projects. These create surplus value by continuously reorganising and harmonising the underlying infrastructure in order to achieve at least an approximation of the goals. The sub dynamics and the levels are reflexively reconstructed through discussion and negotiation in the triple helix (fig. 4)

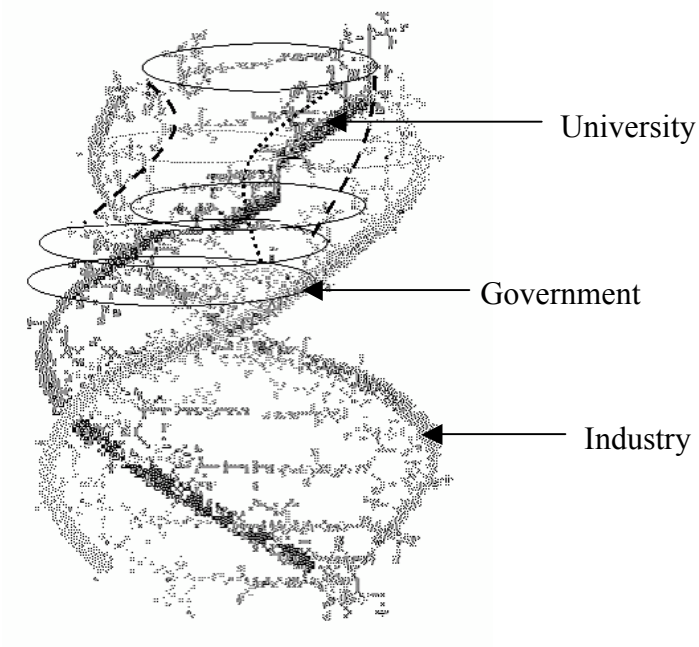

Figure 4 Evolving networks of communication between the actors in the triple helix Model Source: Etzkowitz and Leydesdorff (2000)

A TTO and the commercialisation process can be a product of these reflexive sub dynamics. In a commercialisation process there will be a continuously negotiation between the three helices and thus attempts on reorganisation in order to fulfil the commercialisation. The common goal of the stakeholders will be a successful commercialisation.

Etzkowitz (1997) states that there are four dimensions to the development of the triple helix:

- Internal transformation in each of the helices. This could be an assumption of an economic development mission by the university.
- The influence of one helix upon another. This can be a governmental policy on the university.
- The creation of a new overlay of trilateral networks and organisations from the interaction among the three helices, serving to institutionalise and reproduce

interface as well as simulate organisational creativity and regional cohesiveness. This could be a result of for example public budget cuts at the university that will lead to new ideas and changed strategy.

- The recursive effect of these institutional spheres, both on the helix from which they emerged and in the wider society. This can be observed in science as a result of internal changes within academia.

Hence, new types of tasks in the spheres signalises that one is in a triple helix.

2.5.2 The role of the university in the triple helix model

As already mentioned above, the university has an enhanced and central role in the triple helix model. Etzkowitz (1983) has coined the phrase "entrepreneurial university" to describe the university's new role. This concept envisions an academic structure and function that is revised through the alignment of economic development with research and teaching as academic missions (Etzkowitz and Leydesdorff 2000). A two-way flow of influence is created between the university and the increasingly knowledge- based society, and the distance between the spheres is reduced. Thus research is increasingly translated into economic development through the various forms of technology transfer. The triple helix model can interpret and describe these changes in that it endogenous technology development and knowledge infrastructure of society.

Following the four dimensions outlined above, these can be applied to the university and the transformation to the entrepreneurial paradigm (ibid.):

- Internal transformation of the university helix: As the university expands its role in innovation, it would have to revise its existing tasks. The traditional role and functions are reinterpreted and expanded in light of new goals. Overtime the

university reformulate its mission to incorporate the entrepreneurial paradigm. This will be the acknowledgement of the university's role in economic development.

- Trans-institutional impact between the three helices: Formats for collaborative arrangements should be institutionalised in legal and customary arrangements and the arrangements should take on a flexible form. This could be in the form of amendments to the Act on the universities and colleges.
- Interface processes within the university helix: The entrepreneurial university would have an expanded capacity for intelligence monitoring and negotiations with other institutional spheres. Therefore centralised (and decentralised) interface capabilities will have a leading role during the introduction of the entrepreneurial paradigm to academia. Over time, the interface capabilities will spread throughout the university. The TTO is a typical holder of such a position as a monitor and a negotiator and as an organisation with interface capabilities.
- Recursive effects: The university as en entrepreneur will develop capabilities to assist the creation of new organisations. This will lead to the formation of trilateral organisations, with new cross-organisational and cross-institutional features. This is materialised through the establishment of a TTO.

The establishment of a TTO can thus be interpreted as an expression of the university's recognition of being entrepreneurial.

As described above, there are ongoing transformations within each of the helices. The communication between them preconditions communication skills and knowledge of the language of the other helices. The TTO can be said to have passed through several institutional spheres in the course of its existence and has thus become adept at the translation process. The different sub dynamics in the helices can be expected to select upon each other.

These selections are asynchronous as the helices use their specific codes. When the selections "lock-in" upon each other, as in a process of negotiations, next-order systems may become relevant (Etzkowitz and Leydesdorff 1997 and 2000). These processes can be observed in the work of the TTO: in the process of disclosure to commercialisation of an invention.

From these two concepts outlined above, one might set out the hypotheses that the triple helix concept will be analytically useful to describe the technology transfer process through a TTO. The NIS concept on the other hand, might turn out to be insufficient to captivate the role of the TTO. This will be further elaborated and illuminated through the case of NTNU TTO.

3 Methodology

This thesis is a part of an extensive evaluation of the NTNU TTO (TTO) conducted by NIFU STEP[6] – the Norwegian research institute for studies in innovation, research, and education. The evaluation is divided into three parts: 1. Organisation model, 2. Portfolio – strategies and results, 3. the researchers' attitudes and anticipations towards the TTO.

In gathering information for part 1 and 2 semi-structured interviews and documents studies were used, whilst a survey forms the basis for part 3. The web- based survey was sent out to all researchers at the NTNU including the St.Olav Hospital, Trondheim University Hospital. The responding rate was 43%. This thesis falls in under part 2 as it investigates the tensions and selection mechanisms of the technology transfer process, and through the case study of the NTNU TTO launches a five-phase model of the technology transfer process.

A qualitative approach has been adopted in this thesis. This is a case study of one single organisation, the NTNU TTO. Gerring (2004) argues that a case study is best defined as an intensive study of a single unit with an aim to generalise across a larger set of units. A unit connotes a spatially bounded phenomenon. The case study approach was employed in order to achieve detailed information on the technology transfer process and further to generalise the findings. By using the case study method one wish to know both what is particular to that unit and what is general about it (ibid.). The empirical material has been gathered through interviews and text analysis of documents from NTNU and NTNU TTO. In addition, some information from interviews conducted for the organisational model (part 1) and results from the web-based survey have been used.

[6] http://www.nifustep.no/

The interviews were semi-structured and had open-ended questions. In all the interviews a guideline was partly used. At the TTO we interviewed the managing director, four full-time employed seniors each the head of one of the business areas, the lawyer, the sales manager and two of the juniors employed in the Industry Solution business area. All together nine persons were interviewed in the TTO. The interviews lasted between one and two hours and were conducted in June 2006. The informants were selected on the basis that they had depth knowledge on the technology transfer process, were experienced, and had extensive knowledge about the organisation. All the seniors and the managing director have been involved in some way in establishing the TTO.

One or two researchers from NIFU STEP and myself conducted the interviews. All interviews were recorded, except the interviews with the juniors and one of the seniors. The interviewers took notes during all interviews. The interviews were later written out and the other interviewers approved the report. The recordings were listened through, but not transcribed, and functioned as a back up. Additionally, one researcher from NIFU STEP conducted a second round of interviews to gather more information on critical parts of their evaluation. These have been partly used as supplements in this thesis.

Gerring (2004) argues that ambiguity is to a certain degree inherent in the case study. Due to the heterogeneity of the business areas in the NTNU TTO, the informants had different opinions on the technology transfer process. There will always be an uncertainty in the use of interviews in the process of generalising one case. The informants will give a subjective narrative on the process and it is thus not possible to obtain an objective representation of the technology transfer process.

One limitation of this study is the short existence of the NTNU TTO. It has only been in operation for two years and 6 months (June 2006). A TTO is built on experience and the NTNU TTO is now starting to grasp the technology transfer process. Another limitation is

also that the data and the analysis are built upon the case study of one TTO. It could be valuable to compare two or three TTOs. However, I believe that the model of the technology transfer process developed in this thesis can be generalised to other Norwegian TTOs – they are all apart of the same innovation system. This is also the purpose of the case study, to intensively study a single unit with the aim of generalising to larger set of units.

Below, an introduction of the Norwegian university system and policy will be given before the case of the NTNU TTO is introduced.

4 The Norwegian university system and policy

The Norwegian university sector is mostly public, with the exceptions of a few private colleges. Research funding from the Norwegian public sector has traditionally been substantial. However, there has been an increase in funding to R&D from the National Budget. This is a result of an increased awareness and belief in – especially by politicians, that more R&D will lead to more innovation (Ministry of Research and Education 2005). Thus the universities have an increased and important role in the government's ambition in increasing the countries innovation capacity and capability. Parts of this increase can be seen in figure 5. Except of the high increase in funding from the public[7], the highest increase in R&D expenditure is seen in the column of the Research Council of Norway (RCN). RCN is the principal research policy advisor to the government, and its mandate is to promote and support basic and applied research in all areas of science, technology, medicine and humanities[8]. It functions as an open arena for the competition over funds, it is a coordinating organ for investments in infrastructure and a strategic body that identifies arenas of special effort. The universities have to apply for funding from RCN (ibid.). The purpose is to ensure that the funds are handed out to the best scientists and the best projects. In 2003, 87% of the funding of R&D in universities came from the public sector. The funding from industry appears to have been stable the past seven years.

[7] This increase has been sustainable due to the increase in the number of students at higher education institutions

[8] http://www.forskningsradet.no/servlet/Satellite?c=Page&cid=1138785832539&pagename=ForskningsradetEngelsk%2FPage%2FStandardSidemal

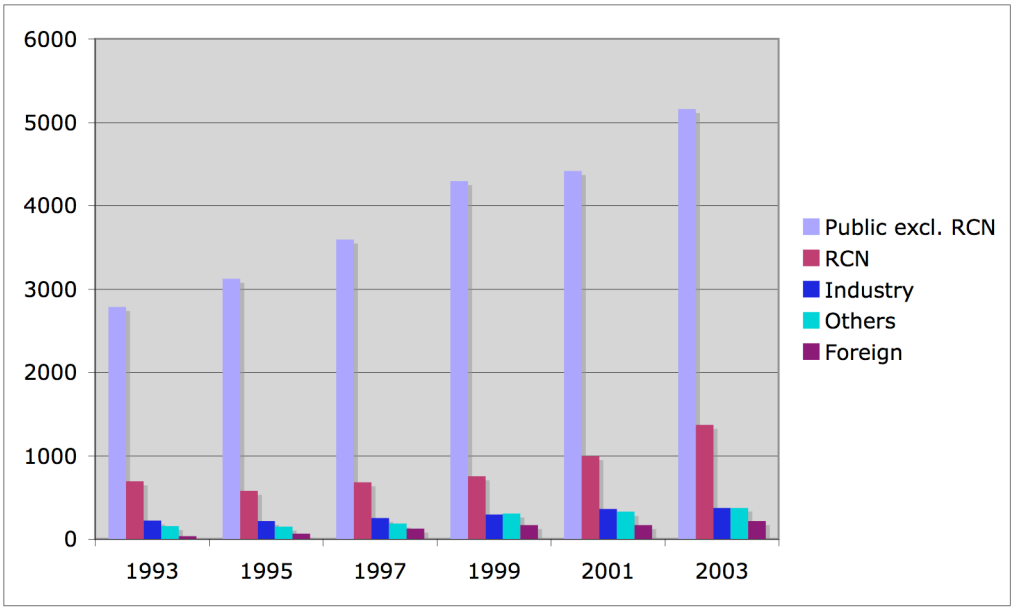

Figure 5 Total R&D expenditure in the university and college sector 1993- 2003 in NOK millions. Source: The report on science and technology indicators for Norway 2003

Norway has thus what we can call a centralised university system. This means that funding stems from a central governmental organisation or directly from the Ministries. Local or regional authorities do not administer the funding mechanisms.

4.1 The act on universities and colleges

In order to enhance innovation, amendments to the Act on Universities and Colleges and to the Act relating to the right to inventions made by employees were made in 2003. The purpose of the amendments is to increase the commercial exploitation of research results at the universities and colleges. This should be performed without threatening the principal traditional tasks of the organisations characterised as free research and higher education (Ministry of Research and Education 2002). The overall objective is to strengthen the transfer of knowledge between universities and industry, and to establish a system that gives society a greater benefit from activities at universities and colleges.

By the amendment to the Act on Universities and Colleges, the universities and colleges were ordered to take on a greater responsibility for exploring the commercial values of their research results. Paragraph 2, 4[9] states that universities and colleges have a responsibility to disseminate knowledge about their organisation and to develop understanding for, and the use of, methods and results in science. This should be communicated to public sector, cultural life and industry. Further it is stated that universities and colleges shall collaborate with the larger society and industry.

The amendment to the Act relating to the right to inventions made by employees was a repealing of the exception for teachers. This implies that it is now the employer, rather than the employee, who owns the right to commercially exploit inventions done by researchers. Previously the researchers owned their own research results, but with the amendment they are now equalised with other employees in other sectors. Researchers still have the right to publish their results, but they are obliged to inform their employer of the invention prior to publishing. They can also publish at the expense of commercialisation. In this way the academic reward system that focuses on the number of publications, has been considered.

The distribution of income from the commercialised research results is not specified in the amendment. Hence, this is up to the organisations themselves to decide. However, a suggestion was made in the commissions report on how the income can be distributed; 1/3 of the income should go to the researcher and 2/3s to the employer.

According to the amendments, which are quite similar to the Bayh-Dole Act, the universities are now committed to establish new functions that shall: motivate the employees to commercialize research results, consider if an invention can be patented or has a commercial potential, file for a patent, divide income from IPRs between the involved parties, administer the IPR portfolio and dispose the surplus from the commercialised

[9] www.lovdata.no

inventions. To administrate this most universities have established a technology transfer office at campus. Most colleges also have contacts with technology transfer institutions.

The TTOs encounter challenges, as they are new actors in the system. The system has evolved and adapted through the interaction of its organisations and institutions over long periods. The introduction of the TTO has thus encountered some resistance and social inertia from the system - especially from researchers who were deprived of a right they previously enjoyed. Such changes in a system will adjust over time, but it is a difficult and challenging process. This will be further illuminated below in the analyses of the NTNU TTO.

4.2 The Forny programme

The Forny programme[10] was established in 2000 (but has been existing as a project since 1995), and is a joint programme between RCN and Innovation Norway. Its prime goal is to increase wealth creation in Norway through commercial exploitation of research results. In order to achieve this, the programme helps research organisations to establish professional systems and new organisations for technology transfer, like a TTO. It has a focus on the attitudes and behaviours of the research communities, so that the search for possible invention for commercialisation will become an integrated and prioritised task. Further, it contributes to nationwide research based business development, and encourages and contributes to increase operation between research sector, industry sector and public sector. The target group of the programme is researchers. These are sought reached through the employers and the TTOs, as well as science parks and other cooperating commercialisation agents.

In order to achieve increased quality and quantity of commercialisations, the programme offers four kinds of funding:

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10 http://www.forskningsradet.no/servlet/Satellite?cid=1088789229237&pagename=forny%2FPage%2FHovedSideEng

- Funding of infrastructure activities. These activities must aim at increasing the researchers and the organisations focus on the commercial potential of research results.
- Funding of commercialisation projects. This can be the process of establishing a new company or handling a licensing agreement.
- Funding of the verification process of a technology.
- Scholarships to researchers which will enable them to focus on the commercialisation project.

The first three funding mechanisms are especially directed towards commercialisation agents like the TTO. TTOs are the administrators of infrastructure activities and most of them have this as a part of their mandate. When an invention is disclosed to the TTO, there is often a need for further development of the technology. The Forny possess thus an important funding mechanism in this development process.

In addition to the four funding mechanisms, the Forny programme offers incentives, like bonuses, for successful completion of commercialisation projects. This incentive system has different criteria which a project must fulfil depending on whether it is a spin-off or a license in order to collect the bonus. The idea is that the whole project is evaluated on its quality and not on quantity. Previously the incentive system was directed towards quantity through the number of spin-offs establishments. Commercialisation agents, like the TTO, are the bonus receivers. Hence, the Forny programme is a selector of inventions for commercialisation; they contribute with funding and offer incentives for commercialisation agents.

To apply for funds from the Forny programme the regional agents of commercialisation have to file a joint application. The goal with this strategy is to bring the

different agents together in order to increase their collaboration, and to establish an arena of information sharing and exchange (Ministry of Research and Education 2005).

5 NTNU technology transfer office

5.1 NTNU

The Norwegian University of Science and Technology (NTNU) is the national centre for education and research within the natural sciences and technology fields. It was established in 1910 as the Norwegian Institute of Technology, and is localised in Trondheim - the third largest town in Norway. The university is multidisciplinary with a major scientific and technological focus and is the second largest university in Norway. Its research is internationally orientated and characterised by expertise in technology, by an interdisciplinary environment and a broad professional scope. NTNU aims at becoming one of the top 150 universities in the world, and among the top ten of scientific and technological universities by 2020. This is sought achieved through increased research efforts, increased student application and interuniversity collaboration, public communication and innovation (NTNU working paper 2006).

5.2 NTNU TTO

NTNU TTO was formally established 22.10.2003. It was established for two reasons: the new amendment that requires the university to contribute to economic development in the society and NTNU's visions and aims of becoming one of the leading universities. The objective of the TTO is that it should be NTNU's primary tool for protecting, administrating, cultivating, marketing and selling IPRs. Additionally, the TTO shall be a driving force for increased commercialisation of research results, and offer employees and students counselling and advising as well as other professional services. NTNU TTO's mandate is to be a strategic body for the dissemination of knowledge from NTNU. Through its actions the

TTO should contribute to create wealth for society. As a back-loop function, the TTO will through deals and partnerships with industry contribute to research, education and innovation at NTNU. It appears like their overall mission is to disseminate knowledge into society and to strengthen the development of the Norwegian society and industry. The economic surplus does not appear to be of an immediate importance for the owner.

5.2.1 Organisation

NTNU TTO is organised as a limited company wholly owned by NTNU. This corresponds with the organisational type "wholly owned" identified in chapter 2 (ITTE 2004). Key features of this type are that it is owned by the university, but is a separate entity that is localised outside the university administration. It enjoys a separate budget from the university and has thus a greater flexibility in pay and incentives to employees. The Board of Directors is independent of the university and the chairman is the University Director. This organisational form limits liability, has general autonomy and gives the university a stronger legal protection against lawsuits.

The organisation of the TTO matches many of the key features of the wholly owned type. The TTO functions as a separate entity located outside the university administration structure. It is co-located with other commercialisation agents just outside the university's main campus. The chairman of the board is the University Director, he chooses the other board members. As described above, the TTO enjoys a separate budget from NTNU and has a general autonomy. Its income stems mostly from services sold to NTNU and funding from Forny. Due to its short existence there is approximately no income from licenses or equity sales yet. In regards to the salary of the TTO staff this is regulated by the government's rates, thus the TTO does not enjoy flexibility in this area. However, the Forny programme regulates an incentive system, and this can give the TTO as an organisation, bonuses for commercialisations of research results. In one area the TTO corresponds more to an

independent type than the wholly owned. This is in regards to competencies and experience of the staff and the commercial form of the organisation. The staffs are independent of the NTNU. This will be further elaborated in the next section.

One of the reasons for the decision on organisational form for TTO was the possibility to deprive NTNU from responsibility in case of external lawsuits. Others were that through this, NTNU could still exercise control over TTO, while TTO still will enjoy limited liability and an autonomous role. The TTO can use the logo of NTNU and still be an equal partner externally, and can draw upon the university's networks. Through this organisational form all rights to commercial exploitation of research results are transferred from NTNU to TTO. The TTO administers the IPR portfolio.

The disadvantage of this form is that there are some difficulties in contacting and maintaining contacts with researchers. The TTO enters an arena where contacts and interaction already are established between the university and the industry in certain fields. After two years of existence there are many university researchers that do not have knowledge about the new amendments and the TTO[11].

The TTO is organized mainly after NTNU's faculties. They have identified four business areas by which they cover all faculties at NTNU:

[11] From the survey, NIFUSTEP report (Spilling, Gulbrandsen and Hanson forthcoming 2006)

Life Science	Science and Technology	Industry Solutions	ICT and Arts
• Faculty of Medicine • St. Olavs Hospital • Faculty of Natural Sciences and Technology	• Faculty of Natural Sciences and Technology • Faculty of Information Technology, Mathematics and Electrical Engineering	• Faculty of Engineering Science and Technology • Faculty of Social Science and Technology Management • Faculty of Information Technology, Mathematics and Electrical Engineering	• Faculty of Information Technology, Mathematics and Electrical Engineering • Faculty of Architecture and Arts • Faculty of Arts

Table 2 NTNU TTO business areas and the NTNU faculties

The business areas are overlapping, which implies that they collaborate closely on some inventions. The present TTO is not specialised though as the TTO business areas cover all faculties. A senior officer is in charge of one business area. The responsible senior has discipline knowledge for his/hers business area. According to some of the interviewees the broad perspective is now changing. A future strategy will be to focus on certain research units where they know there is a lot of invention activity, and try to stimulate these to disclose. This will be further elaborated below.

NTNU TTO has four full time employed business developers/seniors each with the responsibility of one of the business areas. There are also two consultants hired on part time as business developers in Industry Solution. A sales manager, an IPR advisor and a lawyer support the seniors. A controller has recently been hired[12]. In addition, there are for the moment four junior project co-workers working in the different business areas. The aim of this arrangement is to educate entrepreneurs who can manage a spin-off. The initial purpose is that they should work in the TTO for one year and then become an entrepreneur. It appears that from the previous years' groups that most of the juniors now work in already established

[12] This person was not yet hired when the interviews where conducted

companies. The seniors indicate that a lot of resources are devoted to the training and education of the juniors, and there are different opinions on the usefulness of this arrangement. Supervising it all is the managing director of the NTNU TTO. All together, there are for the moment 13 persons employed full time at the NTNU TTO.

5.2.2 Employees and their competencies

Most of the employees have their education from NTNU. They are graduate engineers. One of the employees holds a bachelor of commerce. It is only the managing director who holds a PhD. Two of the seniors have experience from establishing own spin-offs, while one tried to start one but did not succeed. Some of the others have worked in spin-off companies. Most of them have experience from the School of Entrepreneurship at NTNU and the student company START NTNU, which aids students with establishing start-ups and holds courses on innovation. Hence, there are three of the seniors that have the experience of searching for venture capital to finance their spin-offs.

Additionally, the managing director has extended experience and competence in establishing spin-offs. He is what can be labelled a serial entrepreneur, and has established spin-offs in both Norway and US. He also holds a professor II position at the Department of Industrial Economics and Technology Management at NTNU, and has been among other things head of R&D in Sintef – the largest independent research organisation in Norway, and Telenor – a Norwegian telecommunication company.

The business and management experience of the managing director corresponds to the competencies that Siegel *et al.* (2003b) found to be of importance to efficient technology transfer. Some of the personnel also have marketing skills, or experience from marketing. On the other hand there is only one with a PhD and thus extensive discipline knowledge, which were most common in Siegel *et al.*'s study. Thus, this case has an opposite staffing practise than what seem to have been common in Siegel's cases.

There are different opinions on the seniors' own competence. This view was held by the seniors themselves and by NTNU's researchers. Some of the seniors claim that they have the competence needed for the job, and that their technological and marketing knowledge is sufficient. Others are more humble towards the technology transfer process and admit that they would like to have more senior competence in the TTO- someone that has already an experience with technology transfer. These statements indicate that the seniors are not that experienced. It also has to be mentioned that the average age of the staff is quite low.

Some of the researchers' at the NTNU claim that the technological knowledge held by the TTO staff and their professional competence are too low. They argue that the staff's understanding of the technology in question must be on a more advanced level. Hence, it appears that in order to satisfy all demands – from researchers and industry, that optimal staffing of a TTO must be with persons who possess both a PhD and extensive marketing skills and experience. Owen-Smith and Powell (2001) demonstrate that the most critical part in the credibility towards the researchers is not the possession of a PhD, but rather a success story of commercialisation and a perception of the TTO as a facilitator and not a bottleneck in the technology transfer.

The NTNU TTO organisation and its recruiting practises are characterised by what seems to be a focus on spin-offs as the main output of the technology transfer process, when one looks at the previous experiences of the TTO staff. The recruitment of the seniors seems to be mainly from the TTO managing director's own network, whilst the juniors applied for their positions. Some of the seniors were even a bit reluctant in answering the question of how they got the position. All in all it seems like the experience from entrepreneurship activities is the main criterion for employment in the NTNU TTO.

These criteria and competencies are also characterised as belonging to the independent organisational type. This is employed with staffs that have spin-off competence

or venture capital experience. Thus, NTNU TTO has chosen a most commercial form. But even so they can be characterised as belonging more to the wholly owned type because of the relation to NTNU. Hence, there seems to be a tension here between the intention of the owner and the actions of the TTO. This is further evident in that the TTO have now chosen to focus on some research units where they know there is a lot of inventive activity, in order to enhance the possibility of sustainable commercialisations. With this action they move away from the owner's intention of a TTO that covers all faculties and departments.

However, with the commercial form the TTO aims at being more than just a patent- or service office for the researchers. It appears that it is recognised that the technology transfer process is complicated and differentiated, and that it is a constantly learning process. From being entirely employed by personnel with entrepreneurial experience, the TTO is now hiring in other competencies. This is apparent from the employment of an IPR advisor. The employment signalises that the TTO will exercise its IP rights stronger. The lawyer at the TTO claimed that the TTO used a lot of resources on trying to make industry understand that university were not their R&D department. She further claimed that the work of the TTO is perceived by some of the researchers as being too profound and thus the TTO becomes a bottleneck in the technology transfer process for them. These findings correspond with those of Siegel *et al.* (2003a) that more experienced TTOs employ expertise in legal and IPR areas.

This chapter has described the origins and the purpose of the NTNU TTO. It has further described the organisation and the competencies of the employees. Next chapter will analyse the selection phases of the technology transfer process.

6 Selection of inventions for commercialisation

There is heterogeneity between the different business areas. As the managing director said: "We have four TTOs in one". Each senior has his own way of handling the portfolios. Thus it appears like there is no consistent way of handling the process of commercialisation of inventions. This can be related to the dissimilar character of the business areas, and to the seniors' perceived competences and capabilities. However, there are some common selection criteria and mechanism that are employed by all the business areas in the commercialisation process. These will be analysed in this chapter.

Previously the TTO operated with a K0-K5 phase system. This indicated the level of development of the invention. The phases are:

Working with the idea:	**Project development:**
• **K 0 – generation of ideas** Education, search for ideas • **K 1 – concretisation of ideas** Registration of inventor and invention, TTO not actively involved • **K 2 – qualification of idea** TTO does a pre search and qualifies the idea	• **K 3 – concept development** Feasibility of the invention. Assessment • **K 4 – business development** IPR and development of business plan • **K 5 – Spin-off /license** Marketing and sales, negotiations, follow-up of existing IPR agreements

Table 3. K0-K5 phase model Source: NTNU TTO

This model is still used in applications for funds from Forny. As mentioned earlier, the Forny programme requires a joint application for funds from all the commercialisation agents in the same region. All the interviewees claimed that the model is not useful, and that it simplifies the technology transfer process. They are therefore in a process of reorganising the working routines and have not yet developed a new model of the technology transfer process.

6.1 Deal flow

The deal flow is the throughput of the process described above. This includes the number of disclosures, the number of IPR and the number of license/spin-offs from the university (Maartmann-Moe 2006). In the beginning the TTO went aggressively out to search for ideas – they held courses and meetings in order to disseminate their mission and existence. Their approach was soft in the beginning towards the researchers' obligation to report in possible inventions. The goal was to get those who were interested in collaboration with the TTO to disclose. This has changed now. It is recognised that there must be a tougher approach in order to receive more disclosures of higher quality. This is sought solved through that NTNU as the owner, shall stronger signalise that all inventions of commercial potential must be disclosed to the TTO. Hence, NTNU will take on the "police" role so that TTO can continue to build a positive image towards the researchers. This corresponds to the findings of Siegel *et al.* (2003b) that the university's articulation of the technology transfer as a prioritised task is required for successful technology transfer.

In their first search for ideas and research of commercial potential all of the seniors had a top-down approach, where they contacted the management of the departments and the faculties. Some of them experienced low enthusiasm for the TTO as many of the departments and its researchers already had established good relations and networks with industry. According to the senior of Industry Solutions some of the departments perceived the TTO as a straitjacket. Previously the researchers had the freedom to act independently and now they are deprived of this with the new amendment. The seniors experienced resistance from the researchers in trying to make them go through the TTO instead. Hence, most of the seniors were recommended to contact PhDs and students and employ a bottom-up strategy in their search for ideas. The business area of Life Science on the other hand got a very high response

rate, and more ideas were reported than the business area could handle in an appropriate way. Hence, there is a broad heterogeneity between the business areas in the disclosure phase.

Due to this extensive search and the quality of the ideas they received, the TTO realised that this approach gave them too little time to devote resources to take the invention further. Thus, all the business areas have reviewed their portfolio and organisation during the first part of 2006. The senior of Science and Technology said that they "restarted" their business area. This has led to many terminated project and a more critical approach towards new ideas. Their changing strategy and deficient reporting routines (there have been some misunderstandings in the reporting of the different activities) makes it difficult to estimate the deal flow. Hence the table under is based on the K0-K5 phase system.

By August 2006 the total deal flow of the TTO looked like this:

Business area / Phase	Science & Technology	Life science	Industry Solutions	ICT & Arts	Total TTO
Received ideas (K0)	63	93	110	85	351
Concretisation (K1)	42	63	78	66	249
Qualification (K2)	8	31	16	6	61
Concept development (K3)	5	9	7	5	26
Business development (K4)	5	1	3	2	11
Realisation (K5)	3	1	5	0	9

Table 4 NTNU TTO's deal-flow 2004-2006

NTNU set some goals for the TTO when it was established. It was expressed then that the TTO should establish 30 spin-offs per year together with Sintef. The TTO expresses dissatisfaction with this goal, as they perceive that the number is too high. The senior of Life Science said: "Look at Oxford TTO. They have 40 employees and produces eight spin-offs a year!". The TTO has grown by experience and is now more humble towards the technology

transfer process. Many of them said that it is easy to create a spin-off and give it an organisation number, but it is not easy to create a sustainable one. In NTNU's new strategy for innovation a new goal is now expressed: By 2010 there should be a disclosure of at least 200 inventions, which shall result in 10 licensing for cash and 10 spin-offs. By 2020, 200 inventions shall result in 20 licenses and 20 spin-offs (NTNU working paper.2006). It appears like the TTO does not take these numbers and estimates too seriously as the personnel express that they are more occupied by the quality of the output than the quantity.

The TTO has as mentioned changed strategy. One of the new elements of the strategy is the division between what they call Top 10 and less resource demanding inventions. Top 10 inventions are characterised by having a great potential of becoming an invention that can result in huge incomes. Maximum number of inventions within this category is 10. The managing director will manage these inventions. The less resource demanding inventions are characterised by being easy to manage, and will not necessarily have the potential of generating huge incomes. The seniors manage these inventions.

The strategy has the resemblance of the divide between radical and incremental innovation. A Top 10 project will in most cases have the qualities of a radical innovation. If NTNU TTO succeeds in cultivating such an invention they might face difficulties of commercialising the invention. This is due to the possible resistance and social inertia they might meet in their efforts of replacing an existing paradigm. Less resource demanding inventions on the other hand possesses the characteristics of incremental innovations.

6.2 Selection phases

The phases in the technology transfer process were not easy to identify as the TTO recently has realised that the previous system, referred to above, did not fit with the actual process. Based on interviews with the TTO and documents studies, this thesis identifies five phases of the technology transfer process. It introduces thus a new model on the technology transfer

process. The phases and the design of this model are based on the chain-linked model by Kline and Rosenberg (1986) and the model of critical junctures and development phases by Vohora *et al.* (2004). The five phases are (1) research phase; (2) assessment phase; (3) development phase; (4) proof of technology phase and finally (5) transfer phase. Each phase is intended to characterise a specific group of activities that must be overcome in order to move to the next phase. The technology transfer process and its phases are presented in figure 5. The analysis indicates that the technology transfer process move through a number of successive phases in their development in a non-linear way. All the phases are depending upon each other. The arrows between the phases indicate this duality and that the phase is not clear-cut. An invention may commute between two phases. The arrow from the transfer phase to the research phase indicates that the development of a technology can have an impact on new research.

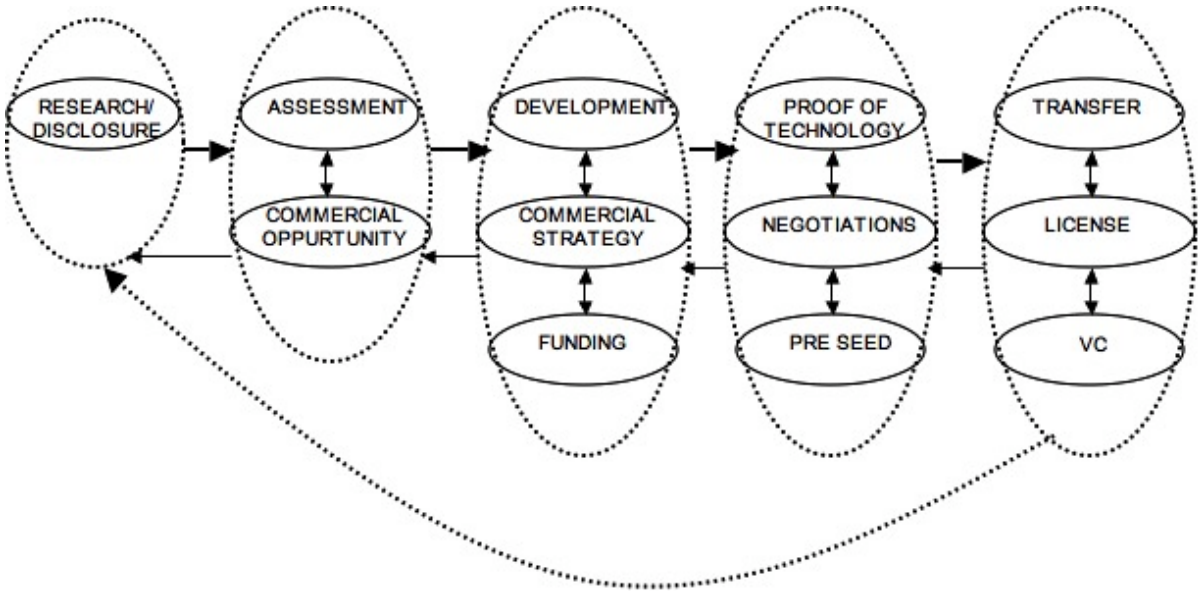

Figure 6 The technology transfer process.

6.2.1 Research and disclosure phase

The overall input to the technology transfer process is research and disclosure of inventions. As described above, the TTO has been through a learning process and they are now employing another strategy to increase the quality of the disclosures. This is sought done through specialisation and focusing of their searches. Implications of this strategy are that they will select some research groups that are known to be active and have a focus on these, instead of trying to encompass all. Criteria for such a group will be, according to some of the informants, that the group is large enough, that they have a common history, some kind of financing in the bottom and that they are open towards commercialisation. The outcome of these specialised searches will hopefully be an increased awareness of the commercialisation possibilities and encouraged researchers as well as some successful commercialisations.

Additionally, most of the business areas experience now, after extensive marketing, that some of the invention are disclosed without them pushing the researchers. Researchers send a notice to the TTO either per e-mail or phone. If the invention is of interest it is disclosed. The first phase of the technology transfer process is thus a dialogue between the researcher and the TTO. The person from the TTO that has the initial meeting can be anyone – a senior or a junior. The staff said that this is related to time and capacity of the TTO personnel and thus the "receiver" of the disclosure does not have to be specialised in the inventions discipline.

As mentioned earlier in this paper, the disclosure of invention is the critical element in the technology transfer process as these create the possibility of variation. Corresponding with the findings of Jensen *et al.* (2003), the TTO staff claim that the so-called Edison quadrant research is not reported to them. If so happens they believe it could be an attempt to "whitewash" the innovation, in order to satisfy the demand for reporting in an invention. This implies that in these cases the disclosure of the invention is only a formality, because in

reality the invention is already commercialized. It was further claimed by one of the juniors that the TTO did not receive the really potential ideas. It seems like most of the disclosed inventions belongs to the Bohr quadrant and is in the early stage as argued by Colyvas *et al.* (2002). Some of the inventions are from the Pasteur quadrant, but this is rather an exception than the rule.

Inventions that researchers report themselves appear to be of higher quality. This is the impression that the TTO staff have. One explanation may be that these disclosures are a result of highly motivated researchers and that they have not been "dragged" into the TTO. This corresponds to findings of Chukumba *et al.* (2005) that older TTOs are more likely to receive disclosures. Owen-Smith and Powell (2001) found that TTOs that have cultivated a positive culture and that were not perceived as bottlenecks by the researcher received high quality disclosures. On the other hand, the researchers' perception of the NTNU TTO is not entirely positive (Spilling *et al.* forthcoming 2006), and the TTO has a challenge here.

The improvement in the quality of the disclosures indicates that the TTO has got a broader stand at NTNU. Additionally it indicates that the intermediary role of the TTO is getting more accepted, since it is selected as a commercialisation partner by some of the researchers. Thus in this phase it is only the researcher that has a selection mechanism and can expose some criteria.

All the disclosures are transferred to next phase, which is here characterised as the assessment phase.

6.2.2 Assessment phase

First of all, when the invention is confined to a business area, the TTO must gain an understanding of the technology. For some of the business areas this can be a time-consuming activity depending on the stage of development of the technology. Due to the heterogeneity, business areas like Life Science experience many inventions in an early stage

whilst Industry Solutions have more developed inventions disclosed, where the degree of complexity varies. During the technology understanding process, the officer will get an impression of the researcher or the researcher group. The TTO measure them on their personal appearance, presentation and research history. The seniors claimed that these initial meetings were important for the selection of inventions for further commercialisation.

After disclosure of an invention, the seniors must uncover whether NTNU owns the IPR or if the ownership is already signed over to someone else, e.g. that it might be an external company that has sponsored the research. Interviewees revealed that external ownership of the IPR is a major problem and obstacle to the technology transfer process. All of them expressed great frustration towards the contract management at NTNU. “Everyone at NTNU can sign a contract with a firm” one of the seniors said and called for a centralised contract management. Many of the seniors expressed that this function could be located within TTO. Additionally there is no central archive at NTNU which can give an overview. Hence, a lot of resources are devoted in this process to clarify the ownership of the IPR.

When the internal IPR situation is clarified, the TTO must consider whether the invention is unique or if it already exists. This is done through searches in patent databases, Google and other databases. If it turns out that the invention can be characterised as new, it must be identified and documented a need in the market for the invention. This process is labelled “commercial opportunity” in figure 5. The business areas conduct the initial market analysis quite differently. Industry Solutions uses internal consultants (researchers) at NTNU, which has extensive knowledge and networks in the area concerned to advice them on the applicability of the invention. They also use external contacts in the market as consultants. Others, like ICT and Arts, uses only external networks in the assessment process. Due to the complexity and the long development process in the Life Science business area, the consultant services are in this phase normally bought from professionals outside of NTNU.

Consultants from other TTOs are also used. On the other hand, some of the interviewees claimed that Science and Technology does seldom use any consultancy services at all. It is claimed that they together with the inventor(s) possess enough knowledge about the industry and the potential markets to do the assessment themselves, and that they have sufficient discipline knowledge to assess the potential of the invention.

Already in this phase the TTO should together with the researcher commence the process of creating a commercialisation strategy. This implies that there have to be made a decision on whether the invention should be licensed out in return for cash or if a spin- off should be considered (license for equity). If the last strategy is an alternative, the seniors underscored the importance of the involvement of the researcher. This is where the assessment of the competencies of the researcher(s) is essential. Vohora *et al.* (2004) argue that decisions made in this phase are critical for success in the following phases and for a sustainable result.

The involved actors in this phase of the commercialisation process are the researcher, the TTO and the market. These agents are all selecting upon each other. First of all, the researcher or researcher group have to choose if he/ they want to continue the process of commercialisation. Second, the TTO selects an invention for commercialisation on the criteria of whether there is a perceived commercial opportunity, a possibility for IPR application, a uniqueness, and if the researcher(s) appears to "have what it takes" to go through with a commercialisation. The TTO personnel reported that the attitude and the personality of the researchers are important ingredients for a successful commercialisation, as they have a major role in both the development and the sales process. Third, the market is of course an important selection mechanism in their identification of needs. Here it seems to be important for the TTO to have the right contacts and advisers. Another selection criteria employed in the assessment phase by the TTO was gut feeling. Sometimes the overall

impression of the invention and its possibilities was the foundation for the decision on whether the invention should be further commercialised or the process should be terminated.

The selection process in this phase has similarities with the triple helix concept. The three helices select upon each other. However, in this phase the main interaction is between the university and industry helices with the TTO as a bilateral intermediary agent, while the government helix is passively present through its institutions (fig. 6).

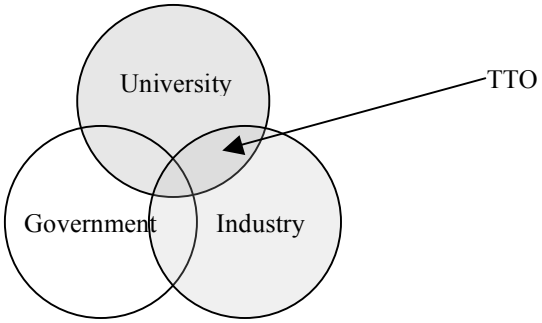

Figure 7 The activity in the triple helix no 1. (Shade indicates activity).

Central actors are researchers, market and TTO, but it appears like it is the TTO – the intermediary agent, which makes the decision on further commercialisation. The TTO act in this case as a bilateral agent between the university and the industry helices. Their contacts and networks both towards the university and the industry, and their competencies are arbitrative for the decision.

The main interaction between university and industry could also be translated to a relation between user and producer as described by Lundvall (1992). According to his description, the relation between user and producer will condition the scope and direction of the process of innovation. This relationship is characterised of a reciprocal flow of qualitative information. The TTO reports that some of the disclosed inventions in this phase are terminated on their part. This is due to that the services of the TTO are no longer needed and

the researcher and industry continues the commercialisation process without the TTO. This implies that the concept of NIS, as described by Lundvall can be used in this phase on some cases. These cases are normally characterised by Pasteur or Edison research. It is uncertain whether the TTO regards these as a TTO success or not. There appears that the routines for what they should register have hitherto been unclear.

If the invention is selected for further commercialisation it moves over to the "development phase". From the assessment to the development phase, the TTO personnel indicated that approximately halve of the disclosed inventions are selected for further commercialisation. In cases where inventions are not selected, the researchers have the right to develop the invention further. The researcher will then own future IPR, and the TTO have resigned theirs and thus NTNU's rights to ownership.

6.2.3 Development phase

Depending on the stage of development of the invention, this phase is usually devoted to verification of the technology. The verification process might be the development of the technology in a laboratory and/or in testing environments. This is the phase where it is normally filed for a patent (if needed). Decisions on whether to patent or not are complex and difficult. First of all there is always great uncertainty connected to the commercialisation of an invention. There are no guaranties that the patent will generate economic returns and that there will be a successful commercialisation. The TTO may end up with managing an inactive patent portfolio that can develop into a so-called patent cemetery. Second, patent applications are rather expensive- especially if it is applied for a global patent. Due to the risk connected with the patent application, the NTNU TTO uses mostly foreign patent offices. The seniors of Science and Technology and Life Science perceive these to possess more knowledge on the technology involved than the Norwegian patent offices. ICT and Arts and Industry Solutions use both foreign and national ones, depending on the invention involved.

Three of the business areas have established a professional council that can be brought in as external consultants in this phase. Life Science does not have any council. The councils consist of persons with either a societal position or with extensive experience from industry. They do not get paid for the job, but they perceive the work as honourable in that they are trusted with the position and that their knowledge can make a difference. The purpose of the council is that the seniors can gather them if they have an invention that they are insecure about in what further action to take. This arrangement has not yet been used. It is especially related to Top 10 inventions.

At this point it must be considered if the invention qualifies to be categorised as a Top 10. Criteria for a Top 10 invention are that there must be a probability for a cash exit at minimum 40 million NOK or a potential of minimum 100 million NOK in surplus within 4 years. Another criterion is that there must be a good team that can realise the potential of the invention. The invention can either be a platform technology, which can be licensed out several times and extended, or a spin-off. The TTO compares the potential of a Top 10 with a new Norsk Hydro[13]. The interviewees disagreed upon whether they possessed such a potential project in their portfolio. The managing director and some of the seniors claimed that at present four to five such inventions were in the portfolio. Other seniors said that they had none. Thus, there is a disagreement upon the criteria for Top 10 inventions.

In this phase a commercial strategy must be implemented. The commercial strategy develops over all the phases and it is constantly evaluated. There should in this phase be made an extensive market search to identify possible customers. All of the seniors, except the senior of Industry Solutions, said that they perceived the Norwegian market as small and that the market for their technology were usually found abroad. They also claimed that they were concerned that if they licensed out the technology to a Norwegian firm there would not be

[13] Norsk Hydro were founded on an university invention by Professor Birkeland www.hydro.no

enough knowledge and competence to make use of the license' potential and valuable knowledge could be lost. Then the dissemination process of knowledge would be terminated. Thus for the moment, license for cash was the most employed commercial strategy.

All TTO personnel agreed upon that it is difficult to establish a spin-off in Norway, due to the lack of experienced entrepreneurs and the possibilities of surrogate entrepreneurs. This is consistent with findings of Vohora *et al.* (2004) that found that spin-offs without an experienced entrepreneur had less potential for sustainable returns. The licensing out for cash strategy does not correspond with the employment strategy of the TTO. It is as previously mentioned, a focus on entrepreneurial knowledge and experience that appears to have been prevailing in the hiring of personnel. This is also apparent with the junior project co-worker arrangement. The managing director admits that after the two years of experience, he would probably have select employees on different criteria if he should to do it all over again today.

Funding of the verification process is also a central part of this phase. The TTO and researcher apply for monies and funds from firms and governmental organisations such as RCN, the Forny Programme, Næringslivets Idéfond (the industry's fund for ideas) and Skattefunn (a tax return arrangement for R&D investments). Funding from firms are characterised by what TTO labels as "kind" monies, which are typically funds that big companies have for aiding technology development. These support the development process without expecting grandiose returns. This is not perceived as the optimal solution by the TTO, as this supports only part of the process. Firms can instead take a lead in the development of the invention by investing monies all the way through the proof of technology phase. The TTO will then only have a passive project management role, while the researcher and the industry are developing the invention together. In return for this investment the firms get "first – right – of - refusal" or an exclusive license.

When applying for funds from the RCN and the Forny Programme, the TTO personnel reported that they had to establish a R&D company based on the invention in order to achieve funding. This company can either continue to function as a spin-off, or it can be what the TTO calls an "early phase" company that licenses out the technology. After the establishment, the TTO must send in a project application. This was reported to be time-consuming work. If the application is rejected, there is a possibility for a second application. The juniors are often confined to the job of finding funds, and some of them complained that many commercialisation of an invention were terminated in this phase because of lack of funding. Thus, verification monies in the development phase are a major selection mechanism. The invention is dependent upon funding for further development. By lack of funds the development of the invention will either be terminated or halted temporary.

In the development phase four actors are identified: researcher, TTO, firms and organisations that can provide verification monies. As in the previous phase, these actors select upon each other in various and interactive ways. If the researcher does not expose significant capabilities and resources, or if there is not established a well functioning team, there are no potential of becoming a Top 10 invention. If the TTO does not implement the right commercial strategy, there will be no sustainable results, and if the potential customers are not found there will be no sales. The inventions that are terminated are in most cases due to the limitations in technological development.

Hence, the helices are selecting upon each other. However, in this phase, all three helices are actively involved as indicated in figure 7. The triple helix pattern is here evident.

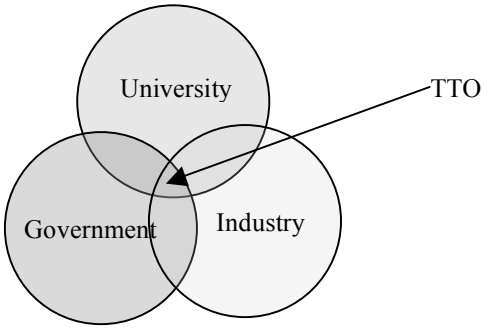

Figure 8 The activity in the triple helix no 2. (Shade indicates activity)

The governmental helix selects through its funding mechanisms, the industry through its funding mechanisms and its needs, the researcher with his/her competencies and motivation. The TTO functions in this phase as an intermediary between all helices in most of the cases. Here the TTO has the trait of a trilateral organisation.

The user-producer relation is present here in the relationship between the university and the industry. But, it appears that it is not useful as analytical concept in captivating the role of the governmental funding mechanisms. If the firms on the other hand take on a lead in the development of the invention all through the technology transfer process, the NIS concept can be useful.

It appears that it is no longer the TTO that makes the decision on continuation of commercialisation. Opposite to the previous phase, where the TTO had direct influence upon the decision, it is now in the hands of the other agents to make the decision. TTO functions here more as a service organisation and an organiser. This means that if the TTO has done good work in the assessment phase, there should be diminishing obstacles for further commercialisation. If all factors are successfully present in the development phase: verification monies, patent, potential customer, commercial strategy, motivated researcher etc., the invention processes to the next phase. Due to the many factors involved there can be

long delays between the phases. The invention can then travel back and forward in this process.

6.2.4 Proof of technology

After the development phase and verification of the technology, the technology must be proofed. In this phase the technology will be tested enough times so that potential risk will be reduced to a minimum. The process can last from three months to several years depending on the business area and the technology involved. At this point the invention must have gained sufficient credibility to requisite resources to start-up a business or to license out the technology for cash. There must be generated returns by offering something of value to the customers. This is thus the last test on the inventions technology and its commercial potential. Inadequacies and deficiencies that have existed during previous phases will lead to problems and crises in this phase (Vohora *et al.* 2004). Seniors at the TTO claimed that if they had done a good job in the previous phases then this phase should not be problematic. The proof of technology phase and the development phase are characterised by strong interaction and overlapping.

Pre-seed funds often finance proof of the technology. This is the phase between verification monies from the governmental organisations/ firms and the subsequent phase where the possibility for venture capital is explored. All the informants complained about the lack of pre-seed monies in Norway. They also complained about the lack of understanding for this type of funding– both from public and industry sector. Especially Life Science complained about this. The inventions here are characterised by long and demanding development processes, with a great capital need. Hence, Life Science has tried to develop its own pre-seed fund. This appears to be growing with among others capital from the Central Norway Regional Health Authority and have now reached the amount of 7 million NOK. The senior compared his situation towards Oxford: “Oxford has a pre-seed fund of over 100

million NOK and they are establishing only eight spin-offs a year. Do you think these get a lot of help or what? They even have Oxford in their name!" He further argued that experienced personnel in England had told him that if you do not have a pre-seed fund, then you should forget technology transfer. Other seniors at NTNU TTO mentioned that there is a new pre-seed company under establishment now.

Potential licenses takers are in this phase continually in a dialog and negotiation with the TTO. The TTO experiences that many of the potential customers are interested in an exclusive license. From this follows a dilemma for the TTO. One part of their mandate is to disseminate knowledge in the society. By granting exclusivity this part could be jeopardised – the dissemination of the knowledge will be minimal and so would the possibility of continued research. This corresponds with the arguments of Mowery *et al.* (2001) and Nelson (2001). They argue that patents and licenses from the university and the secrecy surrounding them are possible obstacles to the dissemination process.

If TTO does not handle the process correctly in licenses negotiations, it might end up being a block in the system. One example provided was a case where the TTO had intertwined in a relation between a researcher and a multinational company. The TTO claimed the right to the invention and are now in a process of negotiations with the firm that has sponsored the research and possible sub-licensers. If they do not succeed in the negotiations, their actions and intertwining might hamper the researcher from further research and the dissemination process of the knowledge might end.

In this phase we find the same actors as in the previous one. The critical part in this phase is to obtain finances to acquire a proof of the technology. This functions as a selection mechanism. Here the role of the firms in selection takes the form of direct involvement in the exploration of the university inventions.

Once again, there is a resemblance between the triple helix model and the interactions of the agents. As in the previous phase the three helices select upon each other, some are more dominant than others. The commercialisation process is characterised by uncertainty, and even though there has been done extensive assessments there might be difficulties in this phase. In this phase the industry helix has a dominant position in that it contributes to the further development and is the potential buyer. The government also holds a strong selection mechanism in its establishment of pre-seeds funds.

The user- producer relation and the NIS concept are present in this phase in cases where there is an interaction between the university and industry helices. Especially in cases where a firm has the lead in the technology development of the invention and the TTO has a passive project manager role.

From this phase to the subsequent the technology is almost completely developed. It appears that many processes strands here. NTNU TTO administers around 30 patents and several of them are ineffective. One reason for this large number of ineffective patents might be that the assessments of the feasibility of the invention have not been conducted satisfactorily. Some documents even state that there has been filed for a patent without a commercial assessment. In effect NTNU TTO administers now a patent cemetery. When confronted with this, they all agreed that this was not an optimal position, but they had had to act so in the beginning in order to create some results. After two years they are now to a large extent more critical towards filing for a patent if the use and need is not documented properly. This is also reflected in their employment of an IPR advisor and a sales manager. Hence, for the moment there are few inventions that actually are in the transfer phase.

6.2.5 Transfer phase

In this phase, one of the main challenges TTO encounter is locating venture capital (VC). Vohora *et al.* (2004) found that too many potential spin-offs contact VCs too early –often in the development phase. In that phase the potential of the invention is not comprehensible, and thus there is no VC to be raised. This is also the argument of NTNU TTO, that without the pre-seed funds the VC will not be interested in the invention.

The seniors had different opinions on the access to VC. Some claimed that this was quite good. Others found that the VCs were more sceptical towards spin-offs from the university – in total it appears that there has been a decrease in VC supported spin-offs. In addition the senior of ICT & Arts argued that the competencies of the local investors were not the best. The senior of Industry Solution claimed that the threshold for spin-offs is higher than licenses for cash. Shane (2002) claims that VCs turns to university spin-offs as a last option. He further argues that this might be due to that spin-offs are a last resort strategy for commercialisation of an invention and that the patent is ineffective. The reason is that the license is not attractive for the industry and thus spin-off is the only option for commercialisation. Google is an example of this.

Hence, in this phase there will hopefully either be a license contract, a spin-off or a contract on further R&D. A licensing for cash transaction demands a lot of pre -work. NTNU TTO has just signed a license contract and this has been a long negotiation process to secure the realisation of the license' potential. Such a contract contents milestone plans for realisation. If these are not realised the contract can either be terminated or the firm has to pay an economic compensation. The seniors underscored the importance of having a secure contract on further use of the license. As mentioned earlier, the imperfect estimate of the value of the knowledge may entail a market failure (Bercovitz and Feldmann 2005), and the negotiation will always contend an element of uncertainty.

The agents participating in this phase is related to the chosen commercialisation strategy. In a spin-off case there will be the employees, the TTO, a VC and the environment (geographical localisation, other firms etc.). In a case like this the TTO normally holds equity. This means that the TTO convert time used for product development into equity. The NTNU TTO holds equity in seven companies for the moment. Most seldom they contribute directly in a spin-off with cash. A R&D company established for applying for funds from governmental organisations will involve the researcher, the TTO and industry. The transfer of licenses to industry involves primarily the TTO and the customer, and often the researcher is participating in the negotiation process. This applies to the negotiation of a license for cash as well.

The transfer phase is characterised by interaction between the university, represented by the TTO, and the industry. The government is again present in this process through its institutions, but not through the direct involvement by its organisations. However, it is present ex post commercialisation with the Forny Programme's incentive system and bonuses per commercialisation. The triple helix concept asserts that the spheres selects upon on each other and the selections "lock-in" upon each other, and then an innovation may become relevant (Etzkowitz and Leydesdorff 2000). It might be argued that the transfer phase is the materialisation of the lock-in by the selections. A spin-off can be such a materialisation. If the invention has been developed so far, then there is a high probability that it will be commercialised.

The transfer phase can also be explained by using the NIS concept. Here it is asserted that innovation occur in firms (Lundvall 1992, Nelson 1993, Edquist 2005). The transfer phase is described by an extensive interaction between the user and the producer – the producer is here represented by the TTO and most often the researcher(s). The firm possess here a dominant position, and its actions are crucial for the commercialisation, especially in

negotiation of license sale. When a spin-off is established or a firm has bought a license the firm and the spin-offs becomes the producers and then potential customers are the users.

This chapter has identified five different, interdependent and interacting phases in the technology transfer process. There are different actors with different roles relating to one another in each phase and they are all interwoven into an intricate network. Next chapter will discuss the tensions of the technology transfer process identified in this and the previous chapters.

7 Discussion and conclusion

The research question initially asked in this thesis was: What characterises the technology transfer process of a newly established TTO? The previous chapters have explored the technology transfer process through the NTNU TTO. Throughout this thesis there have been a discussion of the characteristics of the technology transfer process, and five phases have been identified. However, the role of the TTO in the technology transfer process reveals several tensions. In organisational theory tensions are often related to decision-making and organisational design alternatives. These are perceived more or less conflicting or incommensurable and circumstances might make it very difficult to choose only one of the alternatives (Gulbrandsen 2005). This is apparent in the case of the NTNU TTO. Tensions are here found in TTO's strategy, how the TTO relate to their owner, what type of research that is disclosed to the TTO and the TTOs role in the system. In addition there are tensions in the interaction between the actors participating in the technology transfer process. Some of these tensions have already been described in the previous chapters and they will be further elaborated below.

First of all, there are tensions within the TTO and how they handle technology transfer and its features. The TTO has employed a new strategy for easier identifying possible Top 10 projects or so-called blockbusters. In order to obtain a disclosure of possible Top 10, the TTO will specialise their searches and focus on research groups that they know have a high proportion of inventive activity. There are several tensions attached to this strategy.

In employing this strategy the TTO takes the role of an independent type TTO. They move away from the intentions of the owner NTNU, which were that the TTO should be an administrator of NTNU's IPR, a driving force for increased commercialisation and a strategic

body for dissemination of knowledge from NTNU. The intention behind this is that the TTO should build an entrepreneurial culture at NTNU through covering all faculties, departments and researchers. The broad focus is also apparent in the organisation of the TTO and their business areas. TTO's new strategy might send the wrong signals to the research community in communicating that they will only focus on commercial researchers. With this they might close the door for potential inventions from hesitant researchers, and hinder cultivation of an environment for disclosing. Owen-Smith and Powell (2001) found similar results in their study. TTOs who had a sole focus on big successes hinder efforts at cultivating high quality researchers who have been hesitant to disclose and patent. However, it appears like the TTOs who can refer to a blockbuster enjoy higher credibility in the research communities. This is evident it in the quality and the amount of disclosures (ibid). Hence, there are several dilemmas in the strategies of NTNU TTO.

Another implication of this strategy is on the quality of the ideas that the TTO receives. As discussed in the previous chapter, NTNU TTO remarks that the really good ideas and inventions, like Edison research are not disclosed to them. These researchers collaborate directly with the industry. Bohr research, which is characterised by research in an early stage, is disclosed to the TTO. These require extensive development and thus a lot of resources before it can be commercialised. Life Science research is often in this stage. Other research can be characterised by belonging to the Pasteur category, which is research that can have the possibility to increase fundamental understanding and can be applied commercially (Faley and Sharer 2005). This type requires development, but not extensive like Bohr. The different research types demand different qualities and resource of a TTO. Hence, the TTO should decide upon what kind of research they aim at in order to achieve that the disclosures hold the qualities requested and that the TTO can offer the services demanded.

All research types can lead to both incremental and radical innovations. With a Top 10 strategy the TTO aims at creating a possible radical innovation that may result in huge revenues. This might encounter difficulties. Radical innovations will either introduce something totally new, or replace an old paradigm (Fagerberg 2005). In case of the latter the TTO will meet resistance from the proponents of the old paradigm. These considerations must be taken in focusing on a Top 10 strategy. This reveals another tension as well between the NTNU as an owner and the TTO. The initial purpose of the TTO was not to contribute to substantial revenue for the NTNU, but rather to disseminate knowledge into the society. The Norwegian university system is public, and the funding of the university has been substantial and increasing over the years. This is opposed to other countries where budget cuts have forced them to commercialise inventions and the expectations for incomes are higher. Thus the articulated need for a Top 10 is in a tension with the intended strategy of the TTO.

Further, the TTO encounters tensions in their relationship towards industry. Previously firms exploited directly upon university research. With the introduction of the TTO they must now pay for research and inventions that previously were perceived as free, and contacts with the university often have to be channelled through the TTO.

The new amendments by which the NTNU TTO is a result of deprived the researchers of a privilege – the right to own their inventions. TTO is thus a new actor in an already established system that has been evolving and interacting for years. Systems use long time to adapt to changes, and it will probably take time before TTO is integrated and perceived as a natural organisation in the system. This implies that the TTO will encounter a lot of scepticism towards their work. This is evident in the researchers attitudes towards the competencies of the TTO personnel and. Even some of the TTO personnel appear to doubt if the TTO as an organisation possess sufficient competencies. Hitherto low success rate of commercialised inventions may be an explanation for this doubt. Success is dependent upon

many factors, among others competencies, the rate of disclosure and other organisational features like capacity. These factors are interdependent and one alone cannot explain the low rate of success. However, Owen-Smith and Powell (2001) found that the main challenge for a TTO was to cultivate a positive disclosing environment. The number of TTO personnel with PhDs was unimportant for the disclosure quality.

The resistance from the researchers and the system can be explained by the NIS concept. Main components of the NIS are organisations and institutions and the relations between these. Firms are in this concept the main loci for innovation and these explore upon the university research (Nelson 1993, Edquist 2005). In this system there appears to be no room for a TTO. This is evident from the previous chapter. The chapter illustrated that the NIS concept is constructive as an analytical device in cases where there is a direct interaction and collaboration between the university and the industry - a user-producer relationship where there is a reciprocal flow of qualitative information (Lundvall 1992). Other tensions in the NIS concept are related to the possibility of that the TTO can become a bottleneck in the technology transfer process. Patenting and the secrecy surrounding the work of the TTO are by several proponents perceived as possible obstacles to the dissemination of knowledge into society (Nelson 2001).

The national aspect of the NIS appears also to be under tension in this case. The new amendment and the Forny programme indicate that university research should contribute to national innovation and economic development. Informants from the TTO admitted that they perceived the Norwegian market as too small, and the knowledgebase of Norwegian firms were considered by some of them to be insufficient for the development, commercialisation and further use of inventions. Thus, most of the TTO's commercialisation strategies are direct towards firms and markets abroad. It appears then that the Norwegian market does not

capitalise on the governments policy effort as might have been expected with the introduction of the amendments.

However, it appears from the case study that the TTO is a facilitator in cases where there is a need of further development of the invention before it can be licensed out either through cash or equity. The analysis of NTNU TTO illustrates this through the triple helix concept. The triple helix concept can through the dynamic interactions of the three helices of university, government and industry, describe and explain changes between and in the organisations. It explains and grasps the evolution of new organisations, like a TTO, through the different sub dynamics in the helices that select upon each other in asynchronous ways (Etzkowitz and Leydesdorff 2000). The triple helix can through this explain the role of the TTO in the technology transfer process where the different helices are involved in both direct and indirect ways. Within this process there are tensions between the helices as their selections are asynchronous. Thus, sometimes an invention that is perceived to be of commercial potential by the TTO is terminated because of lack of funding from government or industry. Further there are also tensions between the altered roles of the TTO employees, as they have to act as intermediaries between the three helices. These roles change trough the phases. It appears that the TTO have to negotiate in all helices simultaneously and that they have to stimulate the different needs of the actors in order to achieve a successful technology transfer.

There is obviously a tension between the NIS and the triple helix concepts in their perception of the role of the TTO in the technology transfer process. Nevertheless, it appears like they are complementary, and not contrasting, in explaining the technology transfer process and to capture the different cases. Both concepts have been helpful in identifying the characteristics of the selection phases and the role of the involved actors in this thesis. Where one was insufficient as an analytical device the other one appeared to be helpful.

We have through this thesis seen that the technology transfer process of a newly established TTO has several characteristics. The efficiency and the success of the technology transfer process are dependent upon the institutions and organisations that interact with the TTO. Without the support of these the technology transfer process is inhibited and it is difficult to establish successful commercialisations of inventions.

This implies that the technology transfer process must be studied in the context of the system that surrounds it. Only through this one might grasp the whole situation of the TTO and what features that characterises the technology transfer process.

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